SEWAGE WORKS JOURNAL

VOL. XXI MAY, 1949 NO. 3

Special Features

Chlorinated Hydrocarbon Effects on Sulfides—
Eliassen, Heller and Kische

Sewer Maintenance at Milwaukee—Knapp

Metalworking Waste Treatment—Unwin

Deinking Waste Treatment—Morgan

OFFICIAL PUBLICATION OF THE

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OF THE

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IN CONJUNCTION WITH

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FEDERATION OF SEWAGE WORKS ASSOCIATIONS
325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

YOU NEED BOTH HALVES OF THE SCISSOR

In the CHICAGO Comminutor the cutters and shear bars cut and chop; the channel feeds and holds.

The combination of channel and rotating drum makes the CHICAGO Comminutor the only effective method for cutting and screening sewage solids in the stream.

Engineering details of exclusive CHICAGO Channel Designs for any sewage flow are available to engineers on request.

Over 2000 successful installations prove "You Need Both Halves Of The Scissor"

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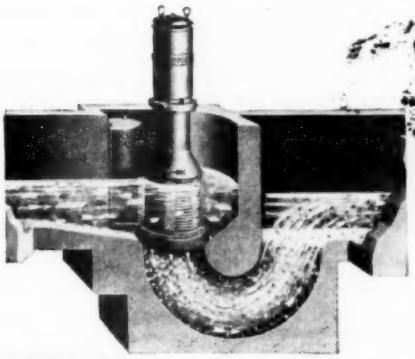

Cross section of a CHICAGO Comminutor channel illustrates a typical design of controlled discharge channel. Sheared small particles must pass through a maximum drum slot width of 3/8 in. Comminuted matter completely settles out in the primary tanks.

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SEWAGE WORKS JOURNAL

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A bimonthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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Prince and Lemon Sts., Lancaster, Pa.

EDITORIAL AND EXECUTIVE OFFICES

325 Illinois Bldg., Champaign, Ill. Send all manuscripts, advertising copy, subscriptions, address changes, etc. to this address.

SUBSCRIPTION RATES

Members of local sewage works associations affiliated with the Federation, $3.00 per year.

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Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879. Accepted for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in part 4, Section 538, P. L. & R., authorized October 4, 1945.

INDEX SERVICE

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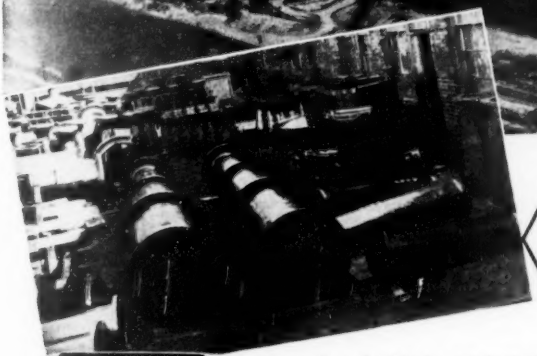
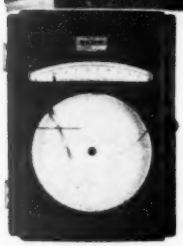
ALMOST A BILLION GALLONS A DAY!



World's Largest Sewage Treatment Plant Uses Venturi Meters



More than double its original size, the Southwest Plant of the Sanitary District of Chicago now treats almost a billion gallons of sewage each day. In the recently completed addition, Builders Venturi Meters ranging from huge 8' diameter units down to 4" diameter meters measure the sewage, sludge, and air flows. These reliable meters are the backbone of a well-integrated controlling and metering system that's vital to the efficient operation of this . . . the **world's largest sewage treatment plant.**

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4	100" Raw Sewage Meters
1	78" Return Sludge Meter
8	66" Mixed Liquor Meters
1	20" Waste Sludge Meter
69	Air Meters (72" to 4")

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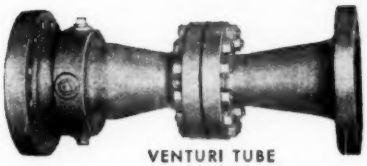
MO METER



VENTURI TUBE

The correct design and careful workmanship of Simplex Venturi Tubes insure stable coefficients over wide velocity ranges, enabling the accompanying meter to measure flow with extreme accuracy. The high efficiency in the utilization of the differential pressure head is the result of more than 40 years of manufacture and research by this company.

Simplex Type MO Meters, when used in conjunction with Simplex Venturi Tubes as primary devices, guarantee the utmost accuracy in flow measurement over long ranges. They can be furnished to measure accurately over ranges of 20 to 1, 25 to 1, 28.5 to 1 or 32.5 to 1.

Where flow ranges are long, a single meter often will be sufficient where two or more ordinary instruments would otherwise be required.

For full information and bulletins, write to the Simplex Valve & Meter Company, Dept. 5, 6719 Upland Street, Philadelphia 42, Pa.

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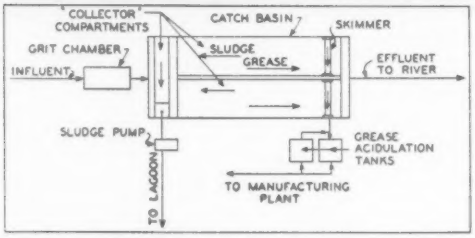
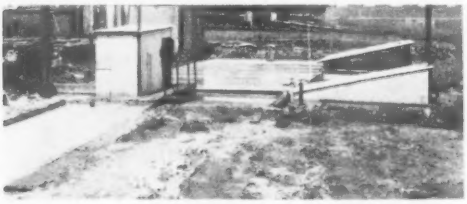
VALVE AND METER COMPANY

LINK-BELT sludge collectors
recover 1100 lbs. of valuable grease daily



Flow diagram of industrial waste treatment plant at Delany & Co. glue works. Link-Belt equipment collects sludge, recovers grease, assures excellent performance.

Looking toward effluent end of catch basin. The cross pieces seen on liquid surface are the redwood conveyor flights of two parallel Link-Belt sludge collectors. These flights are slowly moving the floating grease to effluent end of tank, where operator will skim it off by hand-lever operation of a Link-Belt Rotoline grease skimmer.



General view of waste treatment plant as seen from influent end of catch basin. Grit chamber appears at left.

Increase Operating Efficiency.....

Recovery of 1100 pounds of valuable grease every day is achieved through the installation of Link-Belt sludge collectors and Link-Belt Rotoline grease skimmers in an existing waste treatment catch basin at the glue manufacturing plant of Delany & Co., Inc., Philadelphia, Pa. The operating efficiency of the catch basin also was increased, although the rate of flow of industrial waste averages 47,500 gallons per hour.

Link-Belt equipment — including screens, sludge collectors, mixing, aerating, conveying and driving machinery—has long been "first choice" of consulting engineers, public officials and industries where solids and grease are removed or reclaimed from waste water. This durable, dependable equipment is designed and manufactured in our own plants.

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Philadelphia 40, Chicago 9, Indianapolis 6, Atlanta, Dallas 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8. Offices in Principal Cities.

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SCREENS · COLLECTORS · MIXERS · AERATORS

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As at past A.W.W.A. conferences, we will have a full-scale working model of the hydrant on display. Many of the delegates are probably familiar with this product; and so far as they are concerned much of our time no doubt will be given over to meeting old friends and discussing matters of common interest. We look forward to it with great pleasure.

As for those of you who have never seen the Mathews, we hope to meet every one of you, too. Stop by and let us show you why it is so often said that cities protected by Mathews Modernized Hydrants are the safest.

MATHEWS HYDRANTS

Made by R. D. WOOD COMPANY

Public Ledger Bldg., Independence Square, Philadelphia 5, Pa.

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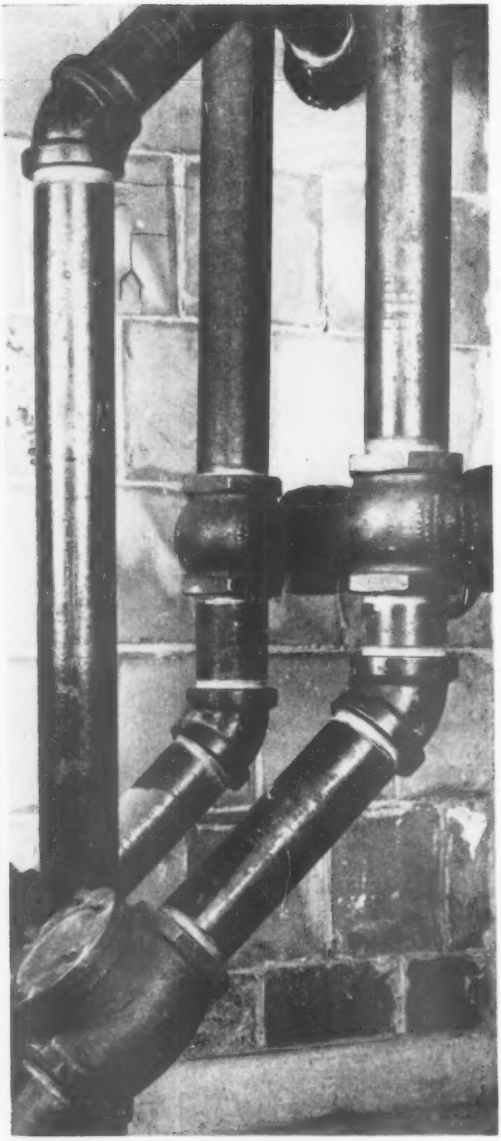

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Centrifugally cast, Clow I.P.S. Cast Iron Pipe is the answer to many of the problems that confront sewage treatment plant engineers. This specialized pipe is suitable for small lines to aerator plates in activated sludge systems as well as lines for coils in digestion tanks . . . also in great demand for miscellaneous pipe lines where it is convenient to have the cast iron pipe cut and threaded on the job. Meets requirements of Fed. Spec. WW-P-356 for downspouts and vent lines, but is also suitable for water working pressures up to 125 pounds.

Available in sizes 3 and 10-inch, 16 ft. long (random) and 4-6-8-inch, 18 ft. long (random) in plain or threaded ends.

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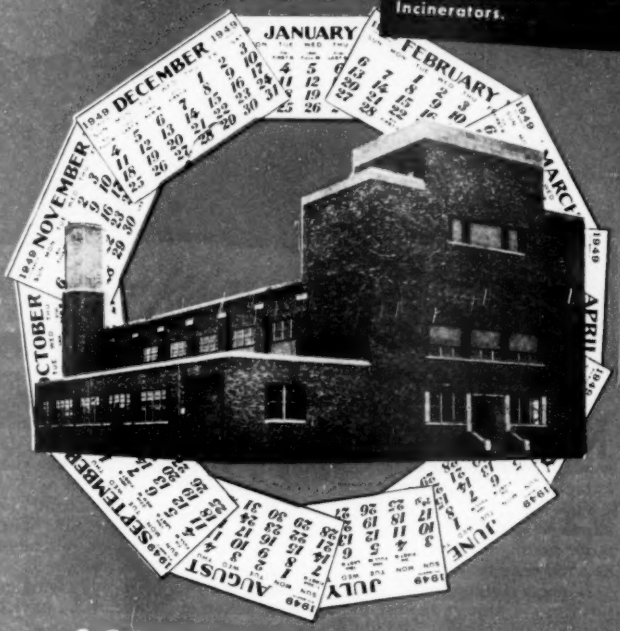
How dependable is a Sludge Drier-Incinerator?

The answer is found in operating logs of sewage plants using Nichols Multiple Hearth Drier-Incinerators.



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May 24, 1946 to March 26, 1947—306 DAYS

April 25, 1947 to March 18, 1948—348 DAYS

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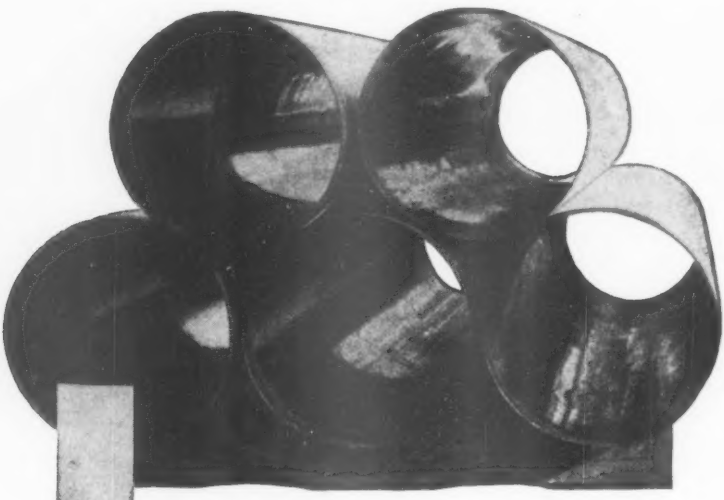

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KOPPERS BITUMASTIC* 70-B ENAMEL gives this pipe a glass-smooth, high-gloss interior surface that permits high flow capacity the day it is put into the ground. More important, it assures a flow capacity equally as high after 10, 20, or more years' service.

Flow capacity remains high because Koppers Bitumastic Enamel forms a barrier against corrosion, rust and tuberculation inside the pipe. The exterior coating of Koppers Bitumastic prevents corrosion from soil and other external conditions.

Koppers Bitumastic Enamels keep water from reaching underlying metal surfaces . . . protect against the corrosive action of chemicals . . . have high electrical resistance . . . do not deteriorate with age.

When you specify Koppers Bitumastic 70-B Enamel for your lines, you know you will get long-term, maintenance-free service. Bitumastic Enamels are manufactured from start to finish in Koppers plants . . . Koppers Contract Department furnishes special equipment, competent supervision and skilled workmen for the application job. Submit your problems for recommendations and quotations.

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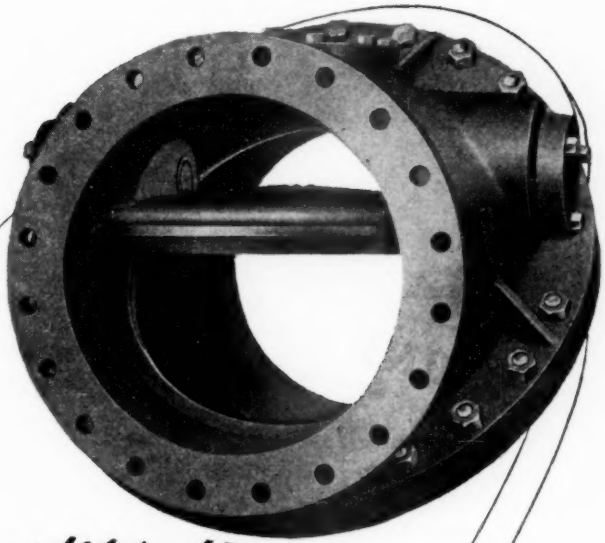


Prevent Water Hammer

with the "CUSHIONED CLOSING" of

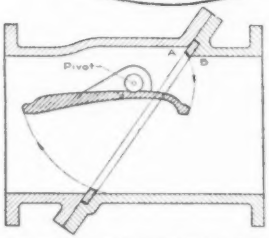
CHAPMAN

TILTING DISC CHECK VALVES

Chapman Tilting Disc Check Valves *work with . . . not against . . . the stream.* As a result, destructive pipe line stresses are practically eliminated. Head losses, as compared with conventional type check valves, are reduced 65% to 80%.

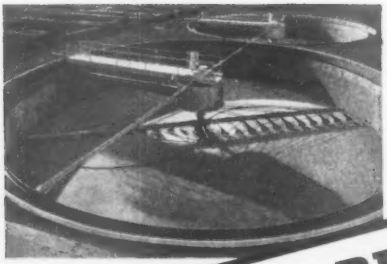
This balanced disc rides smoothly on the flow. It lifts away easily when opening . . . closes quickly and quietly. There is no rubbing on the seat . . . no slamming. Hinge pins, seats and bearings wear far longer.

These are facts. Write today for engineering data and reports of tests. Valves available in either iron or steel.

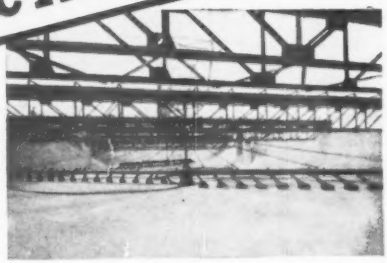


Cross-section of the Chapman Tilting Disc Check Valve illustrating the way that the balanced disc is supported on the pivot, with arrows showing the travel of the disc. A feature of the design is that the disc seat lifts away from the body seat when opening, and drops into contact when closing, with no sliding or wearing of the seats.

The Chapman Valve Mfg. Co.
INDIAN ORCHARD, MASS.



ROUND or RECTANGULAR



Only Rex Tow-Bro Assures Positive Sludge Removal Control . . .

Only the Rex Tow-Bro Sludge Remover gives you positive control of sludge removal from round or rectangular settling tanks over a wide range of withdrawal rates. Because Tow-Bro removes sludge from the tank bottom by a gentle suction instead of the conventional plowing or scraping action, it provides ideal handling of light flocculent solids. Just check these advantages that only Tow-Bro gives you:

***Clearer Effluent** because the gentle suction removes sludge with a minimum of disturbance, assuring a better settling condition and a clearer effluent.

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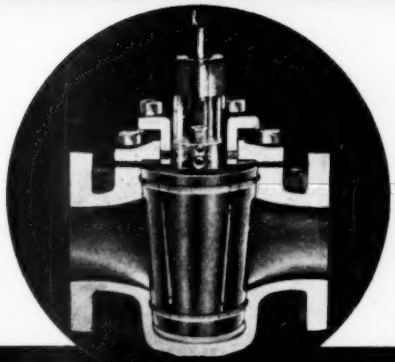

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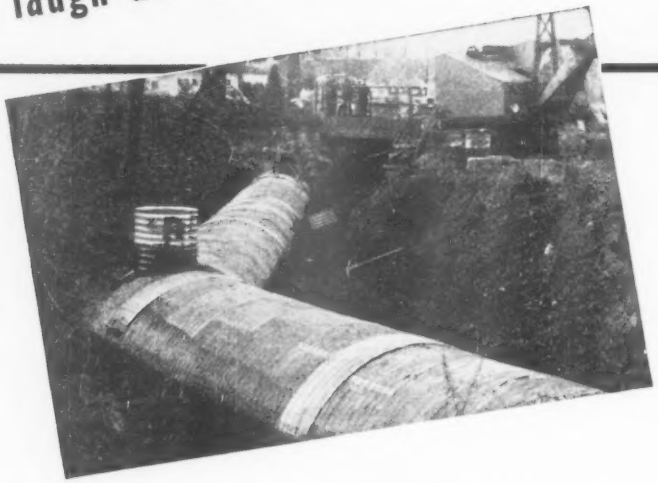

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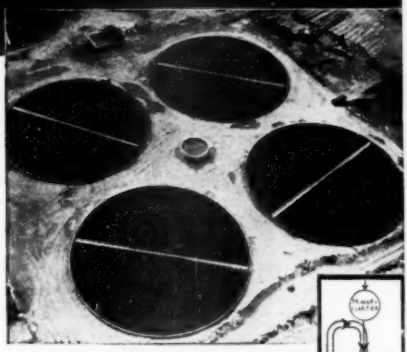

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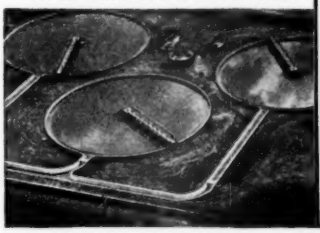

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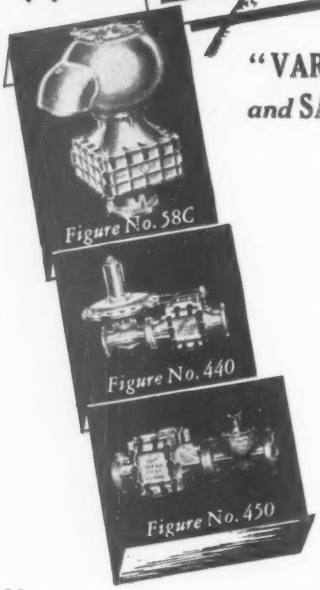

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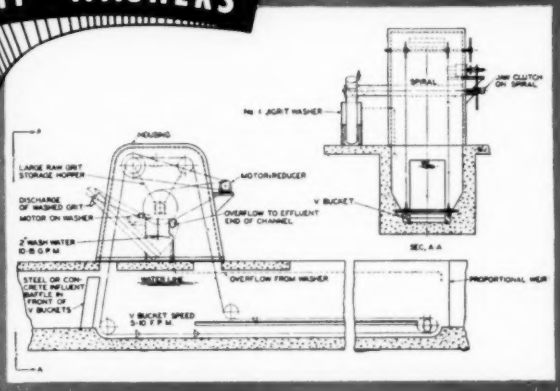

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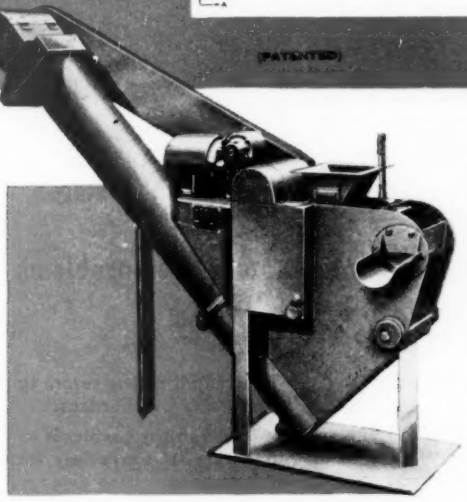

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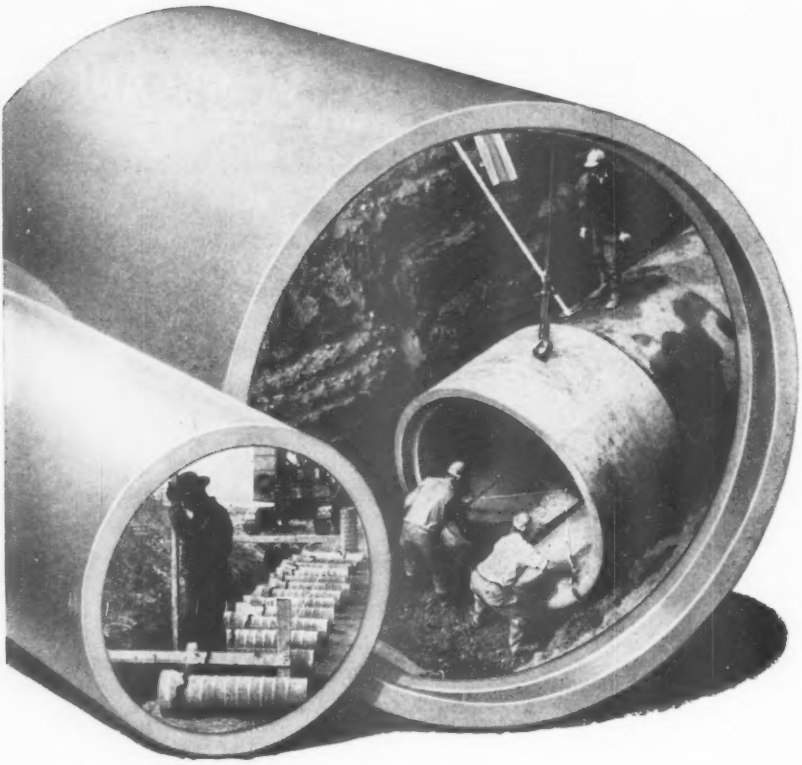

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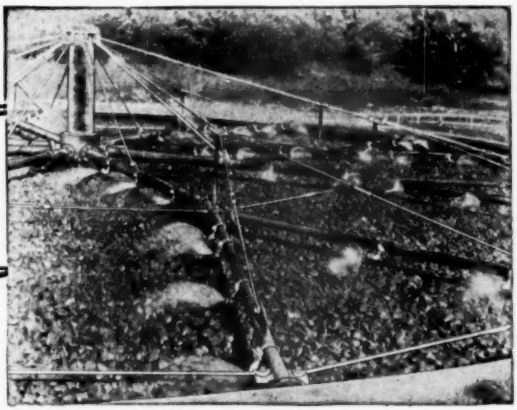

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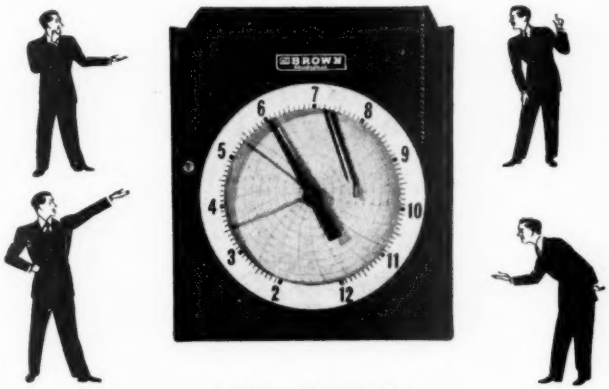

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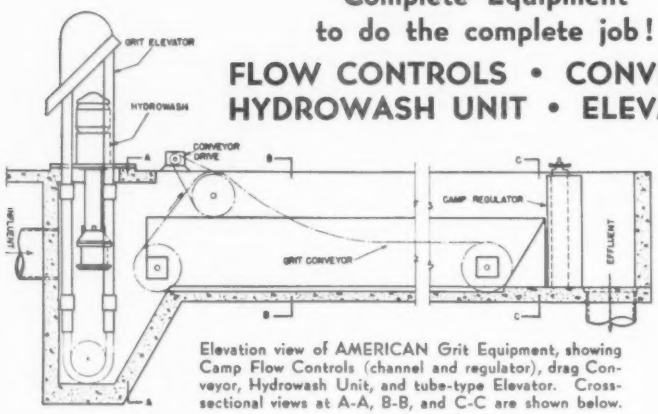

Elevation view of AMERICAN Grit Equipment, showing Camp Flow Controls (channel and regulator), drag Conveyor, Hydrowash Unit, and tube-type Elevator. Cross-sectional views at A-A, B-B, and C-C are shown below.

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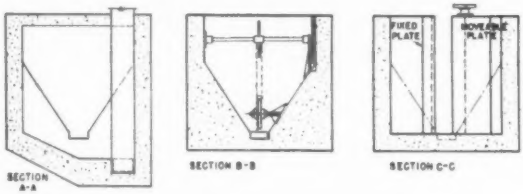

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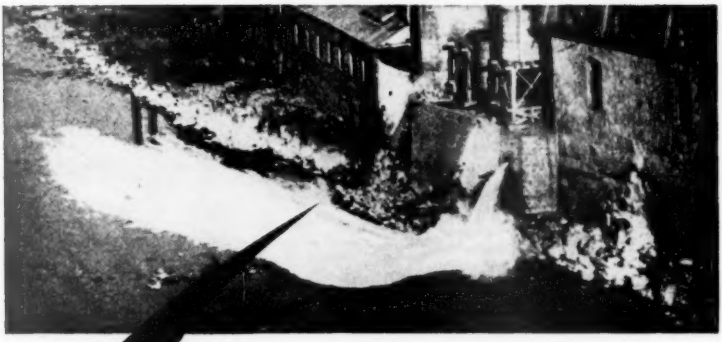

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SEWAGE WORKS JOURNAL

Official Bimonthly Publication — Federation of Sewage Works Associations

Volume XXI **MAY, 1949** **Number 3**

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W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois
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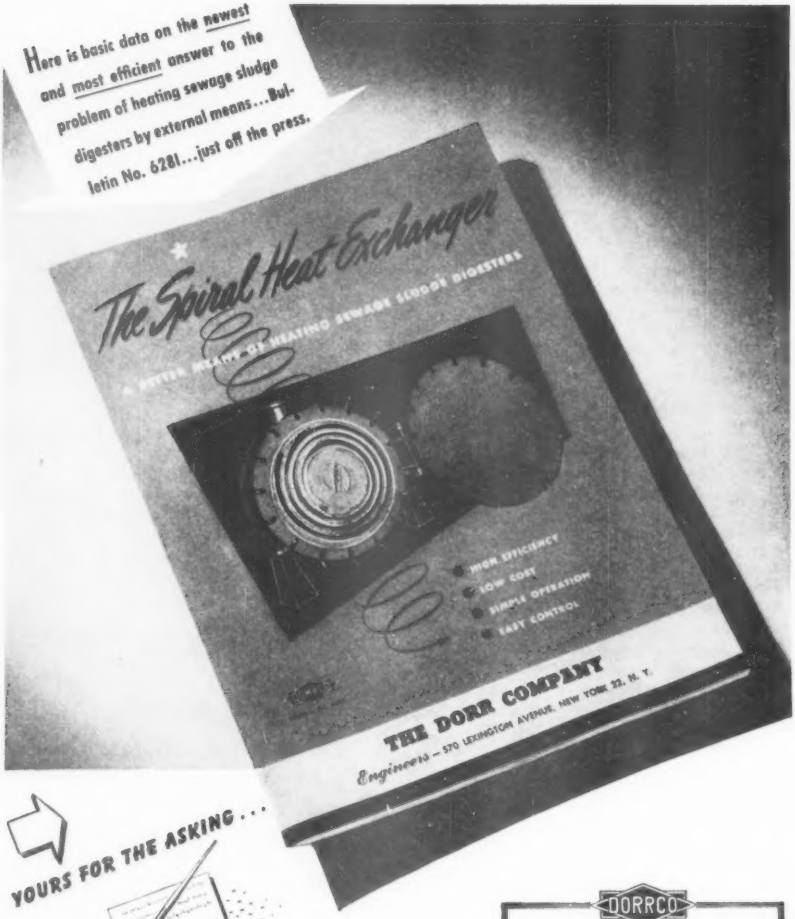

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Sewage Works

THE EFFECT OF CHLORINATED HYDROCARBONS ON HYDROGEN SULFIDE PRODUCTION [1]

By Rolf Eliassen, Austin N. Heller [2] and Gerhard Kisch

Professor of Sanitary Engineering, Research Associate, and Research Assistant, respectively, College of Engineering, New York University, New York

The fundamental principles involved in the various biochemical methods of producing hydrogen sulfide have been the subject of many scientific studies which have been summarized by Waksman (1) and Starkey and Wight (2). Application of these fundamental principles to the problems of sanitary engineering has been undertaken by a number of researchers. Pomeroy and Bowlus (3) have prepared a bibliography of some of these applied studies which included mechanical ventilation of sewers, aeration, and the addition of chemicals to sewage.

In the course of these studies certain basic concepts have been developed. The most important of these is that both organic and inorganic sulfur compounds may serve as sources of energy for bacteria in the production of hydrogen sulfide through biochemical processes.

Both organic and inorganic sulfur-containing compounds are present in normal sewage. The organic sources of sulfur are difficult to evaluate quantitatively since they occur in extremely complex substances such as proteins and their derivatives, among them the many amino acids. The principal inorganic sulfur-containing compounds present in sewage are the mineral sulfates.

Biochemical reduction of sulfates is a major process by which hydrogen sulfide is produced. The microorganisms accomplishing this sulfate reduction have been shown to be a small group of bacteria know as *Sporovibrio desulfuricans*. Starkey (2) has described these as small curved bacteria, frequently of spiral shape, with an average size of 1 μ in diameter by 4 μ long. They have been found in many different environments, including various soils, artesian wells, oil wells, dug wells, mineral waters, fresh and salt water muds and sediments, and sewages. Sulfate reduction has been described (2) as one of the most common and extensive microbiological processes on earth.

Sulfates serve as the source of oxygen for *Sporovibrio desulfuricans* in the respiratory processes, since free oxygen is not utilized by these obligate anaerobes. In the course of reducing sulfates to sulfides the nutritive substances required for the existence and growth of these heterotrophic bacteria are obtained from the ingestion of organic matter as food and the oxidation of this organic matter in the bacterial metabolic processes in which enzymes play an important part.

Food is obtained from many types of organic compounds such as the primary alcohols like ethyl alcohol, polyhydroxy alcohols like glycerine, simple carbohydrates such as sugar, salts of some organic acids typified by sodium acetate, and amino acids. All of these

[1] Presented at Twenty-first Annual Meeting, Federation of Sewage Works Assns., Detroit, Mich., October 19, 1948.

[2] Present affiliation: The Barrett Division, Allied Chemical and Dye Corp., New York.

are reflected in the B.O.D. value of sewage.

In the reaction, sulfates are reduced and the carbon compounds are oxidized by the process of dehydrogenation. This means simply that sulfur, with a valence of + 6 in the sulfate, is reduced to a valence of − 2 in the sulfide, by taking on eight electrons. In any oxidation-reduction reaction, reduction is the addition of electrons to an atom or group of atoms while oxidation, which always proceeds simultaneously, is the removal of electrons from an atom or group of atoms (4).

Hydrogen is the element which assists in the transfer of electrons from sulfur in the sulfates to the organic compounds on which the bacteria feed. Oxygen in the sulfates is also utilized by the bacteria in their respiration. At the same time, the loss of hydrogen by the organic compound serves to decompose that compound into one or more simpler ones. The organic compound gives up some of its hydrogen by means of the catalytic action of enzymes, known as dehydrogenases. Hydrogen in turn is accepted by the sulfur to form hydrogen sulfide. This is what is meant by dehydrogenation.

This process may best be illustrated by a typical reaction in which the sulfate-reducing bacteria consume sodium lactate (pH 5.5) in an acid medium and in the presence of sulfuric acid. The entire reaction takes place under anaerobic conditions. Figure 1 presents the equation for the reaction which takes place with enzymes acting as catalysts. It will be noted that a simpler organic compound, sodium acetate, as well as carbon dioxide, water, and hydrogen sulfide is produced in the biochemical reaction.

The transfer of hydrogen can be visualized more readily if the reaction is further broken down by means of the exploded diagram in Figure 1. The role of each element may then be observed. In the reaction the two sodium lactate molecules, containing three carbon atoms each, are decomposed to two simpler molecules of sodium acetate, containing only two carbon atoms each. The parts of the lactate molecules which are removed are those contained in the (CHOH) radicals. Considering these separately, it will be noted how the sulfuric acid combines so that sulfur accepts hydrogen while simpler compounds are formed with oxygen.

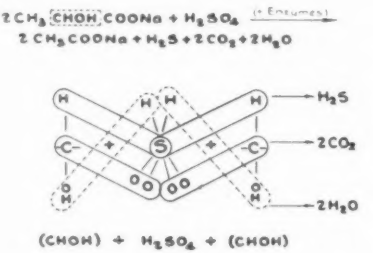


FIGURE 1.—Breakdown of sodium lactate and reduction of sulfate to produce H_2S.

Environment plays an important part in the reactions noted above. Starkey (2) has proven that the pH range for effective sulfate reduction by these organisms is from 5.5 to 8.5. This is within the range of most domestic sewages, even when blended with considerable proportions of industrial wastes. Temperature effects have been reported by Baumgartner (5) and Pomeroy (3), with some sulfide production taking place as low as 4° C. and increasing to values as high as 52° C., which was the maximum temperature at which experiments were performed.

One of the most important characteristics of the environment for growth of *S. desulfuricans* is the oxidation-reduction potential (E_h). Starkey (2) has shown that the effective range of E_h was from − 200 to − 300 millivolts, indicating a strongly anaerobic environment. Dissolved oxygen, nitrites and nitrates could not be present at

this low value of the oxidation-reduction potential.

In sludge digesters and anaerobic soils this range of E_h would prevail throughout the medium. However, in sewers where liquids are flowing at a depth less than the diameter of the sewer, some oxygen might be present in the sewage by solution from the sewer atmosphere above the liquid. This would mean a positive E_h in the liquid near the surface and in the turbulent portion of the flow. However, at the walls and bottom of the sewer a negative E_h might readily prevail, thus providing a favorable environment for the growth of *S. desulfuricans*. Pomeroy (3) and Heukelekian (6) have shown that the slimes and other growths on the walls of sewers, as well as the sludge deposits along sewer bottoms, provide the principal source of these organisms, as well as the most favorable environment for their growths.

Relative numbers of *S. desulfuricans* in sewage and sewers have been studied by Heukelekian (6). The average of five New Jersey sewages was 258 sulfate-splitting bacteria per ml. Contrasted with this low average were the higher numbers found in the growths on sewer walls and in sewage sludges. Analyses showed these to be 6000 and 25,000 per ml., respectively. Heukelekian also showed that hydrogen sulfide production is directly proportional to the numbers of sulfate-reducing bacteria present in the culture medium. These data, together with the greater probability of negative oxidation-reduction potentials at the walls and bottoms of sewers, add weight to the contention that sulfate reduction occurs principally at the slimes and sludge deposits in the submerged portions of the sewer circumference.

These are the fundamental concepts of the production of hydrogen sulfide by *Sporovibrio desulfuricans* in the process of feeding on organic matter and reducing sulfates.

Hydrogen sulfide may also be produced by other means beside the reduction of sulfates. The decomposition of many sulfur-containing organic compounds, such as proteins and amino acids, by microorganisms may lead to the production of hydrogen sulfide as a direct end-product without relying on sulfates as the source of sulfur. Starkey (3) has stated, "Many different heterotropic bacteria are concerned in these reactions. Large amounts of sulfide are thus produced in sewage and in other wastes containing readily decomposable organic materials." These reactions have been studied by Waksman (1), who concluded that the proteins and other organic sulfur compounds are hydrolyzed by microorganisms into simpler compounds and amino acids containing sulfur. Hydrolysis breaks the compounds down further until hydrogen sulfide is produced. Among the organisms which cause these sulfide-producing reactions are the coliform bacteria, *Staphylococcus aureus*, *Bacterium Putrefieus*, and sporogenes. The coliform group, prevalent in sewage, has been found to produce sulfide from a number of organic substances.

From this discussion of the fundamental principles of sulfide production by microorganisms it is evident that organic as well as inorganic sources of sulfur must be considered in devising measures for the control of these microorganisms. The object of the research disclosed in this paper has been to investigate chemical methods for the control of sulfide production from organic and inorganic sources of sulfur to determine the relative significance of each sulfur source in the production of sulfides in sewage.

Control Experiences

Procedures for the control of hydrogen sulfide in sewers have been summarized by Pomeroy and Bowlus (3). Among these are proper design features such as the elimination of extensive

force mains devoid of oxygen, the control of velocities in sewers and junction chambers, and the control of sewage strength, pH and temperature, particularly when dealing with industrial wastes. The cleaning of sewers by mechanical, chemical or hydraulic means to remove slimes and sludge deposits has been discussed by many authors.

Among the chemical means of controlling sulfides, several inorganic chemicals have been used successfully. Hood (7) used copper sulfate in Ridgewood, New Jersey, to destroy roots which caused sewer stoppages and sludge deposits, thus leading to sulfide production in relatively short lengths of sewers in a northern climate. Control of slimes would only be of short duration because they would return shortly after chemical dosage has ceased.

Ferrous sulfate has been used to react with hydrogen and other dissolved sulfides to form a precipitate of ferrous sulfide and thus remove all but 1 p.p.m. (3) from solution. This does not control further sulfide formation below the point of treatment, but will reduce nuisances and corrosion of concrete sewers.

Of the organic substances added to sewage perhaps the most widely used is chlorine. Its activity is not limited to any one phase of sulfide control. Heukelekian (6) has shown that dosages below the chlorine demand will kill *Sporovibrio desulfuricans* and thus minimize the reduction of sulfates. By direct chemical reaction sulfides will be oxidized to elemental sulfur, reducing the dissolved sulfide content of sewage to less than 1 p.p.m. Pomeroy has stated (3) that the average efficiency obtained in oxidizing sulfides when chlorine was added to Los Angeles County sewers was 40 per cent, with a range of 25 to 75 per cent.

Since chlorine is such a powerful oxidizing agent, it not only kills bacteria in the sewage and slimes, and oxidizes sulfides, but also raises the oxidation-reduction potential of the sewage so that many other side reactions take place, thus using up the chlorine very rapidly. It has been the practice of cities to chlorinate at several points on their sewer systems so that sulfide control may be maintained at successive points downstream. As branch sewers join the trunk sewers, new sources of organisms and sulfides are obtained; chlorination must be repeated at each point where these new sulfides become objectionable. Economy plays the leading role in judging the efficacy of chlorine.

Chlorinated Hydrocarbons

Since chlorine is so effective in controlling sulfides, but is so powerful that it is used up too quickly and by too many side reactions, numerous experimenters have sought chlorinous compounds which would release chlorine slowly or otherwise exhibit some of the toxic properties of chlorine, but to a different degree. The ideal chemical for the inhibition of sulfide production in sewage is one which would be specific for the destruction of some phase of the respiratory processes of the microorganisms responsible for the production of sulfides. The toxic effect could be brought about by the destruction of enzymes, the most vital factor in bacterial respiration, or by some detrimental effect on the cellular protoplasm of the organisms. Such a chemical should be effective in small concentrations and also be relatively inert to other substances in an environment such as sewage so that its effectiveness would persist for considerable periods of time. Experiences reported by Pomeroy and Bowlus (3), Brown (10) and Beardsley (11) in California indicate that some of the chlorinated hydrocarbons and other organic chlorine compounds may possess the desired properties.

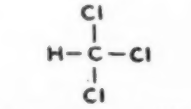
Remarkable discoveries have been revealed within the past decade of the insecticidal and disinfectant properties

of a number of organic chlorine compounds. The symbols DDT and 2,4,D have become household by-words as these chlorinous compounds have demonstrated their insecticidal and herbicidal properties, respectively. It is desirable that investigations be carried out on many of the organic chlorine compounds in order to exhaust the possibilities of applying their unusual properties to the field of sanitary engineering. Huntress (8) has described the properties and formulas of 1320 organic chlorine compounds, many of which have been developed in recent years.

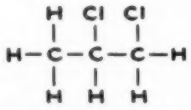
All of these organic chlorine compounds are characterized by having chlorine attached at a number of points in the structure of an organic compound. The relation of these chlorine atoms to the remainder of the organic compounds may most readily be perceived by studying their structural formulas. Three aliphatic (straight-chain) chlorinated hydrocarbons are shown in Figure 2. Three aromatic (ring) chlorine compounds mentioned in the text of this paper are shown in Figure 3. The substances shown in these two figures have up to three chlorine atoms attached to carbon atoms in each molecule.

Greater numbers of chlorine atoms per molecule exist in the organic chlorine compounds shown in Figure 4. There may be some relationship between the number of chlorine atoms and the effectiveness of the compound. It has been reported (9) that for certain insects, hexachlorocyclohexane ($C_6H_6Cl_6$) and Chlordane ($C_{10}H_6Cl_8$) are more potent than DDT, with five chlorine atoms in the molecule ($C_7H_5Cl_5$). Some of the higher chlorine compounds should be investigated before any research program on sulfide inhibition can be considered complete.

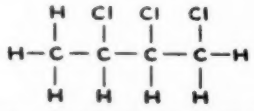
Before outlining a research program to investigate the effectiveness of chlorinated hydrocarbons in sulfide control it is necessary to consider the experience



CHLOROFORM ~ $CHCl_3$

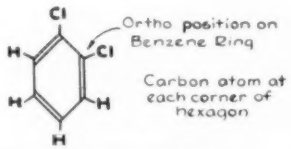


DICHLOROPROPANE ~ $C_3H_6Cl_2$

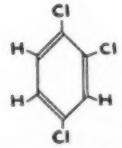


TRICHLOROBUTANE ~ $C_4H_7Cl_3$

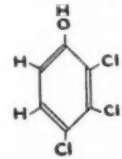
FIGURE 2.—Aliphatic chlorinated hydrocarbons.



ORTHODICHLOROBENZENE
$C_6H_4Cl_2$



TRICHLOROBENZENE
$C_6H_3Cl_3$



TRICHLOROPHENOL
$C_6H_2Cl_3OH$

FIGURE 3.—Aromatic organic chlorine compounds.

of others in this field. Pomeroy and Bowlus (3) reported on some experiences on a laboratory scale with phenol, Cloroben (an emulsion of chlorinated hydrocarbons, principally orthodichlorobenzene), chlorinated propanes, and sodium pentachlorophenate. In these laboratory experiments, chloropanes, pentachlorophenate and trichlorophenol showed the greatest promise. Field results on Cloroben, chlorinated butanes, and chlorinated phenols were reported on the basis of limited data. It was concluded that much more experimental and field results were necessary before definite recommendations could be made.

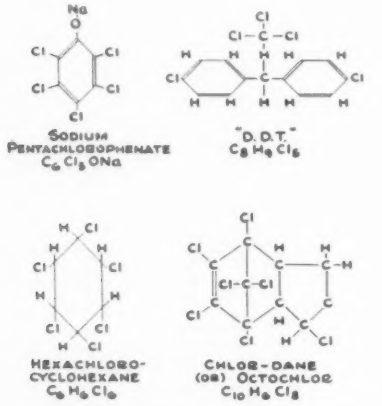


FIGURE 4.—Organic chlorine compounds high in chlorine.

Since the above report (3) was made, considerable work has been done with chlorinated hydrocarbons in Los Angeles and Long Beach, California, and in Oklahoma City. Brown (10) experimented in Los Angeles on a laboratory scale and applied his results to sewer practice. By adding Cloroben to the upper end of large sewers, in quantity sufficient to be equivalent to 1 to 2 p.p.m. at the outfall sewer, Brown claimed to reduce sulfide concentrations by 91.6 per cent. Observations of 15 to 17 p.p.m. of H_2S had been noted in the sewer atmosphere prior to the feeding of these chlorinated hydrocarbons, whereas the average was 1.93 p.p.m. after their addition. Laboratory studies (10) indicated a bactericidal effect of Cloroben on coliform bacteria, particularly when contact times of 5 to 9 hours were available. Brown attributed the reduction of hydrogen sulfide to the slow but steady bactericidal effect of this chemical.

Beardsley (11) experimented with the surface treatment of the walls of sewer pipes with chemicals after a thorough cleaning. His tests indicated that when a 10 per cent emulsion of Cloroben was applied to the cleaned sewers the growth of slimes was inhibited for a year.

In Long Beach, California, Kennedy (12) found that a number of concrete sewers had deteriorated from sulfide attack. In order to reduce sulfides, mechanical cleaning methods and the addition of chlorine were practiced. Later Cloroben was utilized to the extent of 1 p.p.m. This was found to be successful when the chemical was added far enough up-sewer to give as much contact time as possible. Kennedy concluded that a very substantial saving was effected by the substitution of Cloroben for chlorine.

The control of sulfides with chlorinated hydrocarbons in Oklahoma City was reported by Taylor (13). Shock treatment of combined domestic sewage and industrial wastes to the extent of 10 p.p.m. for a short time, followed by the routine addition of 2 p.p.m. as long as hot weather persisted, was successful in reducing hydrogen sulfide odors in sewage being by-passed to a dry stream bed.

Experimental Approach

In view of the degree of success achieved in some cities, together with the lack of uniformity of results in other cities, it was deemed advisable to establish a laboratory procedure for the evaluation of the effectiveness of

various chlorinated hydrocarbons in the control of hydrogen sulfide production by microorganisms. In order to be able to correlate laboratory experiments with published data from field experiences it was necessary to begin the experimental program with Chloroben, the chemical substance for which considerable data have been published. Following this, it would be possible to apply the same procedure in the investigation of the many organic chlorine compounds available in the chemical market. The properties of slow action and long retention of effectiveness possessed by the chlorinated hydrocarbons and related compounds leads one to believe that the eventual answer to the problem of sulfide control may lie in these substances. Final selection of any one compound will depend on the correlation of effectiveness, as disclosed by laboratory and field studies, together with economic considerations.

Experimental Procedure

Studies were made using three types of media in which hydrogen sulfide could be produced. The first medium was cotton-filtered raw sewage from Ridgewood, New Jersey. Two synthetic media were utilized, one with only inorganic sulfur compounds present and the other with mixed organic and inorganic sources of sulfur. The microorganisms chosen for the experiments were first a strain of *Sporovibrio desulfuricans* obtained from Dr. Starkey of Rutgers University, and secondly, the normal mixed population of microorganisms present in domestic sewage. Incubation temperatures were at 37° C. for the *S. desulfuricans* and at 20° C. and 37° C. for the sewage organisms.

Raw domestic sewage containing both organic and inorganic sources of sulfur was obtained from Ridgewood, New Jersey. This was cotton-filtered to obtain a uniform medium. Analyses of the sewage were as follows:

Total Solids	393 p.p.m.
Suspended Solids	36 p.p.m.
Settleable Solids	0 p.p.m.
B.O.D.	121 p.p.m.
Sulfates	48 p.p.m.
Total Alkalinity	75 p.p.m.
pH	7.3

The composition of the synthetic medium containing only inorganic sources of sulfur was as follows:

0.8 gm.	Na_2SO_4
2.0 gm.	$MgSO_4 \cdot 7H_2O$
0.5 gm.	K_2HPO_4
1.0 gm.	NH_4Cl
0.07 gm.	$CaCl_2$
3.5 gm.	Sodium Lactate
0.3 gm.	Ferric Citrate
1000 ml.	Distilled Water

In this medium, as established by Starkey (3), all of the elements necessary for bacterial respiration and nutrition for *S. desulfuricans* were present. Sodium lactate served as the organic food supply for these heterotrophic bacteria in accordance with the chemical reaction noted in a previous section of this paper.

The synthetic medium with mixed sources of sulfur, both organic and inorganic, had the same constituents as noted above, with the addition of neo-

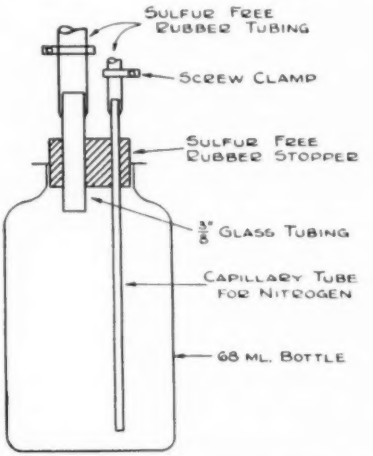


FIGURE 5.—Arrangement of incubation apparatus.

peptone to furnish an organic compound containing sulfur.

All studies were made in 68 ml. fermentation bottles (Figure 5) under conditions which permitted no air to enter the bottle during incubation periods up to four weeks. A new technique was developed to fill, seal and withdraw the sample for analysis without entrapment of air. This procedure will be described in the Appendix. It will be shown that determinations for hydrogen sulfide and dissolved sulfides could be made with a high degree of statistical correlation.

Results

Experiments were conducted over a period of two years using the culture media previously described. Much pertinent data are available. To conserve space only the highlights of the results will be presented here.

Domestic Sewage—20° C.

To the domestic sewage the emulsion of chlorinated hydrocarbons known as Cloroben was added in concentrations ranging from 0.25 to 10.0 p.p.m. by volume. Incubation periods up to 168 hours were used at 20° C. At the end of the runs the untreated control had an average total sulfide content of 10 p.p.m. The results may best be compared in terms of percentage inhibition of total sulfide formation using the control as the basis of evaluation. Table I presents the results on this basis.

TABLE I.—Percentage Inhibition of Total Sulfides at 20° C.

Incubation Time (hours)	Concentration of Cloroben (p.p.m.)				
	0.25	0.5	1.0	5.0	10.0
18	31	40	—	72	57
66	40	54	49	55	47
168	0	15	17	—	15

Domestic Sewage—37° C.

Since there did not seem to be much differences in the effects of dosages from 0.5 to 10 p.p.m. it was decided to attempt a comparison at widely varying dosages, namely 1 and 50 p.p.m., and to increase the temperature of incubation to 37° C. to accelerate the biochemical reaction velocities. The results of this experiment are shown in Table II.

In an attempt to simulate conditions in which high concentrations of *Sporovibrio desulfuricans* are present, such as in sewer slimes and sludges, 1.0 ml. of a 12-hour anaerobic culture of this organism was added to each incubation flask. All other conditions of the experiment remained the same as noted in Table II. These results are shown in Table III.

Synthetic Medium—37° C.

In order to establish a standard procedure to evaluate the effect of chlorinated hydrocarbons in the presence of *Sporovibrio desulfuricans* it was desirable to utilize a reproducible syn-

TABLE II.—Sulfide Production (p.p.m.) in Sewage at 37° C.

Incubation Time (hours)	Concentration of Cloroben (p.p.m.)								
	0			1.0			50		
	H_2S	Diss. S	Tot. S	H_2S	Diss. S	Tot. S	H_2S	Diss. S	Tot. S
18	1.5	2.2	3.6	0.5	0.5	0.9	0.4	0.5	0.8
42	3.4	2.7	5.9	2.3	1.2	3.3	1.2	0.9	2.0
72	6.3	4.2	10.1	4.0	0.8	4.5	2.6	1.2	3.6
168	6.0	6.1	11.7	8.4	0	8.0	6.2	2.9	8.7
336	8.3	3.0	10.7	8.3	5.1	12.9	6.0	5.8	11.4

TABLE III. Sulfide Production (p.p.m.) in Sewage Inoculated with S. Desulfuricans at 37° C.

Incubation Time (hours)	Concentration of Cloroben (p.p.m.)								
	0			1.0			50		
	H_2S	Diss. S	Tot. S	H_2S	Diss. S	Tot. S	H_2S	Diss. S	Tot. S
18	0.8	5.8	6.6	1.3	4.0	5.2	0.6	4.5	5.0
42	2.7	6.3	8.9	3.5	5.0	8.3	1.3	6.8	8.0
72	3.5	6.4	10.5	6.4	4.6	10.6	3.1	4.5	7.4
168	6.7	4.5	10.8	7.0	7.1	13.7	5.2	6.8	11.7
336	7.5	9.2	16.2	9.0	5.9	14.4	4.9	12.8	17.4

thetic medium. The principal constituents of this medium have already been noted. Mineral sulfates served as the principal source of sulfur and oxygen in the anaerobic environment prevailing in the incubation bottles. Sodium lactate was the basic source of readily available organic food. Other organic compounds such as neopeptone, which contains sulfur, were added to this medium as the occasion warranted. It should be understood that this medium is not intended to replace sewage as a medium—since its B.O.D. would be many times that of sewage—but only to serve as a guide to a better understanding of the mechanism of the production of sulfides by microorganisms.

Experiments were conducted under conditions similar to those employed with the sewage medium. Concentrations of neopeptone ranging from 2000 to 50,000 p.p.m. were utilized. The synthetic medium with 20,000 p.p.m. of neopeptone showed sulfide production differences which were statistically significant in evaluating the effects of different mixtures of chlorinated hydrocarbons.

To determine the effect of emulsification, studies were made with the above medium on orthdichlorobenzene dissolved in ethyl alcohol and on the emulsion known as Cloroben. Concentrations of the solution and emulsion in the medium were varied from 50 to 100 p.p.m. by volume. The results of these experiments are presented in Figure 6. The effect of proper emulsification is immediately apparent.

Discussion of Results

Studies of sulfide production in domestic sewage reveal (Table I) that the emulsion of chlorinated hydrocarbons known as Cloroben is effective in inhibiting the production of sulfides at 20° C. to the extent of approximately 50 per cent for incubation periods as long as 66 hours. Concentrations of Cloroben ranging from 0.5 to 10 p.p.m. were approximately of equal effectiveness. This indicates that the chemical possesses inhibitory properties over the microorganisms which utilize sulfur-containing organic com-

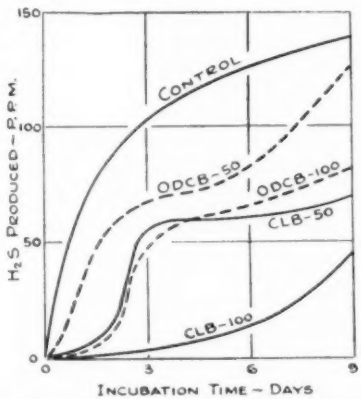


FIGURE 6.—H_2S inhibition in synthetic media using 50 and 100 p.p.m. of Cloroben and orthodichlorobenzene.

pounds and which are normally present in a fresh, medium-strength domestic sewage.

Since the duration of inhibition does not extend much beyond 66 hours it is probable that *S. desulfuricans* develops sufficiently after this period to reduce sulfates in considerable quantities. However, this is a far greater time than it takes sewage to pass through a sewer system so that longer periods are not required for sulfide control in sewers. Another important observation from the results in Table I is that only slightly more than trace quantities of the chemical are required. A concentration of 0.5 p.p.m. was virtually as effective as 10 p.p.m. for 66 hours. This demonstrates the slow but effective action of chlorinated hydrocarbons.

The results obtained with domestic sewage incubated at 37° C. were presented in Table II. For ease of comparison these values may be tabulated on a percentage inhibition basis, using the control portions (no chemical added) as the basis of evalution. Table IV has been prepared in this manner, the columns headed "Sewage" representing results from Table II and those headed "Sewage and Sp. des." from Table III.

As noted in Table II, and in the columns headed "Sewage" in Table IV, 1 and 50 p.p.m. of Cloroben were 75 per cent effective in reducing sulfide production for 18 hours in domestic sewage. At the end of 72 hours, the dosage of 1 p.p.m. was 55 per cent effective while 50 p.p.m. was 65 per cent effective. This was the limiting time of effectiveness for both dosages. It is evident that high dosages are not necessary in relatively fresh sewage unless other factors beside the constituents of sewage enter into the problem.

TABLE IV.—Comparative Percentage Inhibition of Total Sulfides with and without Inoculation

Incubation Time (hours)	Concentration of Cloroben (p.p.m.)			
	1.0		50	
	Sewage	Sewage & Sp.des.	Sewage	Sewage & Sp.des.
18	75	21	78	24
42	44	7	66	10
72	55	0	65	30
168	32	0	26	0
336	0	11	0	0

When active anaerobic cultures of *Sporovibrio desulfuricans* were introduced into sewage in the laboratory experiments a great difference in sulfide production was noted. This is evident when Tables II and III are compared in the columns with no addition of chemical. Sulfide production in 18 hours was 3.6 p.p.m. in the normal sewage and 6.6 p.p.m. in the same sewage inoculated with *S. desulfuricans*. This indicates the important role played by these sulfate-reducing organisms in the production of sulfides in sewers.

The chlorinated hydrocarbons present in Cloroben exhibited only small inhibitory properties in the presence of large numbers of *S. desulfuricans*. After 18 hours of incubation at 37° C., dosages of 1 and 50 p.p.m. of this chemical inhibited sulfide production less than 25 per cent as compared (Table IV) with inhibition of 75 per cent in sewage containing only the normal mixed microbiological population. This emphasizes the need for removal of slimes from sewer walls.

Starkey (2) has stated that the only organism capable of producing hydrogen sulfide by the reduction of sulfates is *S. desulfuricans*.

Since these are present in such small numbers in fresh sewage, as shown by Heukelekian (6), the major production of sulfides in the normal sewage should be attributed to the destruction of sulfur-containing organic compounds, such as proteins and their derivatives, by the normal sewage organisms such as the coliform group. This is further

indicated by the fact that Cloroben will suppress sulfide formation in the normal sewage but not when *S. desulfuricans* is present in abundance. Therefore, it may be concluded that the production of sulfides from organic sources of sulfur is an important factor in the problem of sulfide control.

This importance may be further emphasized by considering the environmental factors governing the growth of sulfide-producing organisms. The coliform and similar groups of organisms in sewage are facultative, meaning that they can grow under aerobic and anaerobic conditions, or at positive and negative oxidation-reduction potentials (E_h). *Sporovibrio desulfuricans*, being strict anaerobes, reproduce most effectively at highly negative E_h values (3), in the range from − 200 to − 300 millivolts.

As the normal sewage organisms consume organic matter in a fresh sewage, any dissolved oxygen is first utilized for bacterial respiration. Unless the supply of oxygen is replenished by solution from the atmosphere of the sewer, or by transfer from other portions of the sewage, the E_h will be lowered to the point where aerobic conditions cease to exist. When the E_h becomes negative the anaerobic environment will prevail. Some of the facultative sewage bacteria will then extract oxygen from organic compounds and may produce sulfides, as previously discussed. As the destruction of organic matter proceeds in the absence of oxygen, the E_h may continue to be lowered until the range is reached where *S. desulfuricans* can reproduce in great numbers and thus reduce sulfates to sulfides. If the state of the sewage can be prevented from being lowered in E_h value to the point of effectiveness of *S. desulfuricans*, the production of sulfides can be inhibited to a great extent.

The reasons for this inhibition may most readily be understood by means of the graphs shown in Figure 7. If

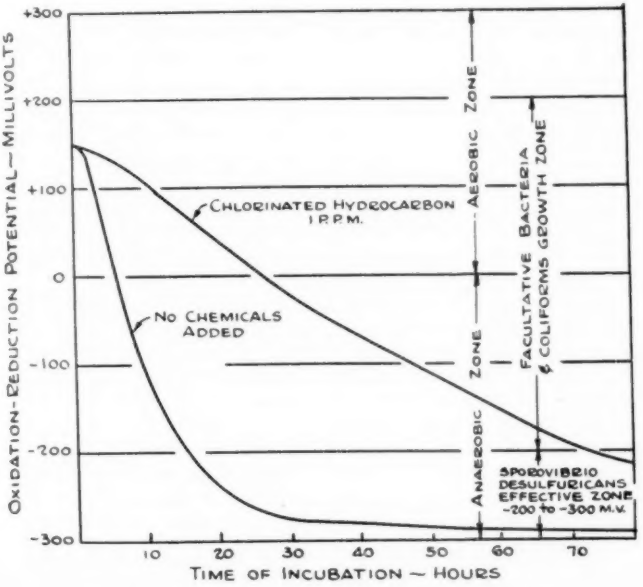


FIGURE 7.—Reduction of O-R potential with time.

fresh domestic sewage, with an initial oxidation-reduction potential of + 150 millivolts, is incubated at 37° C. the potential will be lowered very rapidly by the microorganisms in the sewage. In 18 hours the potential will be lower than − 200 mv. and thus be conducive to the growth of *Sp. desulfuricans* and reduction of mineral sulfates. On the other hand, if 1 p.p.m. of an emulsified chlorinated hydrocarbon is added to the fresh sewage prior to incubation, the O–R potential will decrease less rapidly since the sewage organisms are partially inhibited in their growth. Thus, there is a significant retardation in the production of hydrogen sulfide from organic sources of sulfur.

To control sulfide production, chlorinated hydrocarbons should be added to sewage while in a relatively fresh state, preferably with a positive O–R potential. It is too late to add these chemicals after the sewage has turned black and septic, with high sulfide content, because *Sp. desulfuricans* may be present in large numbers at that time. The alternative would be to treat the septic sewage with a high dosage of chlorine to kill the *Sp. desulfuricans* and oxidize the sewage to obtain a positive O–R potential. Chlorinated hydrocarbons could then be added to maintain the sewage in a relatively fresh state in a manner similar to that previously described.

A more desirable solution to the problem lies first in the removal of the major sources of *Sp. desulfuricans*, such as sewer slimes and sludge deposits. This could be accomplished by attacking the organisms which comprise the slimes, either by solvent action of the chemical or by bactericidal and bacteriostatic actions, thus causing them to be released from the sewer wall.

Methods of accomplishing slime removal were discussed in a previous section of this paper. When the slimes were removed from sewer walls the normal microbiological populations of sewage, including the coliform organisms and small numbers of *S. desulfuricans*, were the only agencies through which sulfides could be produced. The laboratory experiments reported herein have shown that chlorinated hydrocarbons will considerably inhibit sulfide production for 72 hours and will show a very high inhibition for 18 hours. Thus, the laboratory experiments gave results which can be correlated directly with the field experiences previously cited.

The results using synthetic media indicate that a procedure has been established whereby the effects of various chlorinated hydrocarbons may be evaluated. The results in Figure 6 indicate that the prepared emulsion known as Cloroben is more effective in inhibiting sulfide production than a solution of orthodichlorobenzene in ethyl alcohol. The reason for the difference may well lie in the relative dispersion achieved after each has been added to sewage. Since orthodichlorobenzene is insoluble in water, it requires a strong emulsion to achieve the ultimate degree of dispersion required to affect most of the bacteria in the sewage. Therefore, as much attention must be paid to the properties of the emulsion as to the chlorinated hydrocarbon which is the effective inhibitory agent. Studies are being carried out to determine the inhibitory properties of many other chlorinated hydrocarbons so that a more complete evaluation may be made. Properties of emulsions, the hydrocarbons and the dispersing agents can all be studied by the procedure developed in the course of the research reported in this paper.

Summary

A comprehensive review of the literature has disclosed that the mechanisms of the production of hydrogen sulfide divide themselves into two classes. These are categorized by the source of sulfur for the biochemical

reactions. The production of hydrogen sulfide by the reduction of sulfates is the most prevalent reaction. This is accomplished solely by *Sporovibrio desulfuricans*. Hydrogen sulfide may also be produced by the decomposition of organic matter containing sulfur such as proteins and their derivatives. These organic compounds are always present in domestic sewage and are readily decomposed by the normal microorganisms present in sewage, such as the coliform group. In order to minimize hydrogen sulfide production in sewage both types of mechanisms must be investigated and measures devised for each of them.

Consideration has been given to many types of chemicals which have been used with varying degrees of success for the control of sulfides in sewers. In the past few years attention has been drawn to the results achieved in a number of cities by using small dosages of chlorinated hydrocarbons in sewage, thus reducing sulfide concentrations and avoiding nuisance and damage to sewers. Chlorinated hydrocarbons and other organic chlorine compounds have given great promise in other fields through their intensive development by the chemical industry, resulting in compounds such at DDT and 2,4,D. For these reasons it was decided that research should be carried out on the effect of organic chlorine compounds on sulfide control.

This study is of necessity a long one since so many compounds will have to be investigated. Only the first part can be reported in this paper. Since the data already reported in the literature as a result of actual operation of sewer systems have been concerned mostly with an emulsion of chlorinated hydrocarbon called Cloroben, the research undertaken by the authors was concentrated on this substance. This would permit correlation of laboratory studies with actual operating results in large sewer systems such as Los Angeles.

Experiments were conducted in 68 ml. bottles using a medium strength domestic sewage and also some synthetic media. Incubation was at 20° C. and 37° C. for periods of time up to 2 weeks. Hydrogen sulfide and other dissolved sulfides were determined by a new technique developed specifically for this research work. This technique permitted an accurate evaluation of the factors involved in sulfide production.

The results indicated that small concentrations of Cloroben could markedly inhibit the production of hydrogen sulfide in domestic sewage up to 72 hours. Little difference was noted in the effect of concentrations between 0.5 and 10 p.p.m. of Cloroben. It was concluded that low concentrations of this chemical were effective in the inhibition of the normal sewage microorganisms which decompose sulfur-containing organic compounds.

When *S. desulfuricans* was present in high concentrations in sewage, control was not effective until large dosages were employed. The same was true when using synthetic media inoculated with *S. desulfuricans*. Thus, Cloroben does not inhibit the action of these organisms in reducing sulfates to hydrogen sulfide when they are present in large numbers, such as in sewer slimes and sludge deposits. However, it has been shown that chlorinated hydrocarbons will remove these slimes. After removal of the slimes, together with the correction of design and operating conditions leading to sludge deposits, emulsified chlorinated hydrocarbons can be added at a sufficient number of points up-sewer on the main sewers. This will markedly inhibit the normal sewage organisms from producing sulfides by the destruction of organic sulfur-containing compounds.

The chlorinated hydrocarbons will also serve to retard the lowering of the oxidation-reduction potential of sewage and thus increase the length of time necessary to reach a low enough potential favorable to the rapid growth of *Sp. desulfuricans* and the reduction

of sulfates. The retardation can persist for a sufficient time to permit sewage to flow through a long sewer system with no substantial production of sulfides.

Conclusions

1. A new laboratory technique has been developed to permit an accurate evaluation of the inhibitory properties of organic and inorganic compounds in the biochemical production of sulfides.

2. The initial production of sulfides in sewage usually occurs in biochemical reactions in which the mixed population of sewage organisms, such as the coliform group, consume sulfur-containing organic compounds. These reactions also serve to lower the oxidation-reduction potential of the sewage.

3. Secondary production of sulfides occurs when the oxidation-reduction potential becomes lowered to the range from -200 to -300 millivolts. In this range *Sporovibrio desulfuricans* will reproduce in effective numbers to reduce mineral sulfates to sulfides.

4. Chlorinated hydrocarbons such as orthodichlorobenzene, when properly emulsified, will inhibit the initial production of hydrogen sulfide in sewage, and thus keep the sewage in a relatively fresh state for a long enough time to permit passage through a sewer system.

5. A 75 per cent inhibition of sulfide production may be achieved for 18 hours at 37° C. in a normal domestic sewage when the chlorinated hydrocarbons emulsion known as Cloroben is present in a concentration of 1 p.p.m.

6. Concentrations higher than 1 p.p.m. do not increase the inhibitory effect of the chemical to any appreciable extent when applied to normal domestic sewage.

7. High concentrations of sulfate-reducing organisms and septic conditions (low oxidation-reduction potentials) nullify the inhibitory effect of chlorinated hydrocarbons in sewage and specific synthetic media.

8. The mechanism of sulfide production by the reduction of mineral sulfates cannot be controlled by small dosages of chlorinated hydrocarbons and must be controlled by removal of the *Sporovibrio desulfuricans* sources such as sewer slimes.

9. The mechanism of sulfide production by the decomposition of sulfur-containing organic compounds by normal sewage organisms, such as those of the coliform group, can be controlled by the addition of small dosages of chlorinated hydrocarbons.

References

1. Waksman, S., "Principles of Soil Microbiology." Williams and Wilkins Co., Baltimore (1932).
2. Starkey, R. L., and Wight, K. M., "Anaerobic Corrosion of Iron in Soil." American Gas Association, New York (1945).
3. Pomeroy, R., and Bowlus, F. D., "Progress Report on Sulfide Control Research." THIS JOURNAL, **18**, 597 (1946).
4. Pauling, Linus, "General Chemistry." W. H. Freeman & Co., San Francisco (1947).
5. Baumgartner, W. H., "Effect of Temperature and Seeding on Hydrogen Sulfide Formation in Sewage." THIS JOURNAL, **6**, 399 (1934).
6. Heukelekian, H., "Some Bacteriological Aspects of Hydrogen Sulfide Production from Sewage." THIS JOURNAL, **20**, 490 (1948).
7. Hood, J. W., "Copper Sulfate as an Aid to Sewer Maintenance and Sewage Treatment." *Water Works and Sewerage*, **89**, 121 (1942).
8. Huntress, E. H., "Organic Chlorine Compounds." John Wiley and Sons, New York (1948).
9. Frear, D. E. H., "Chemistry of Insecticides, Fungicides and Herbicides." D. Van Nostrand, New York (1948).
10. Brown, R. F., "Up-Sewer Cloroben Treatment of Los Angeles Sewage." *Water and Sewage Works*, **94**, 181 (1947).
11. Beardsley, C. W., "Suppression of Sewer Slimes." THIS JOURNAL, **21**, 1 (1949).
12. Kennedy, D. R., "Sewer Maintenance Experience at Long Beach, California." THIS JOURNAL, **20**, 104 (1948).
13. Taylor, F. S., "Use of Cloroben for Odor Control." THIS JOURNAL, **20**, 917 (1948).

APPENDIX

A Method for the Determination of Hydrogen Sulfide in Closed Vessels

This method permits separate determinations of hydrogen sulfide—both gaseous and dissolved—other dissolved sulfides, and total sulfides, from the same sample of material. It is of greatest value in laboratory experiments where there is a possibility of error due to (1) the escape of hydrogen sulfide, and (2) organic compounds which interfere with conventional methods. The reliability of this method has been checked on a statistical basis and proven valid.

The hydrogen sulfide was produced biologically in 68-ml. culture bottles. The sample was placed in the bottle and the bacterial culture added. When the bottle was ready for incubation it was tightly closed by a sulfur-free rubber stopper containing two glass tubes. One, a capillary, extended to within $\frac{1}{4}$ in. of the bottom of the flask, and the other an outlet tube $\frac{3}{8}$ in. diameter, penetrated $\frac{1}{8}$ in. into the culture solution. Prior to incubation the two glass tubes were sealed by attaching sulfur-free rubber tubing closed by screw clamps. In addition, all connections were sealed with a mixture of paraffin and vaseline. No detectable hydrogen sulfide escaped during incubation periods as long as 4 weeks. The tightness of the seal was determined periodically by testing the incubator atmosphere with lead acetate paper.

Method

A. Hydrogen Sulfide Determination

After attaching the culture bottle in the manner noted in Figure 8, the following method for determining hydrogen sulfide was employed:

1. Sweep entire apparatus, except incubation bottle, with nitrogen gas for 15 minutes. This prevents oxidation of the hydrogen sulfide.
2. After clearing the apparatus, sweep the hydrogen sulfide from the incubation bottle with a stream of nitrogen gas for 4 hours at the rate of 130 bubbles per minute.
3. The hydrogen sulfide is caught in two Erlenmeyer flasks containing saturated zinc acetate solution.
4. Add excess standard iodine solution.
5. Back-titrate with standard thiosulfate solution using a starch indicator.

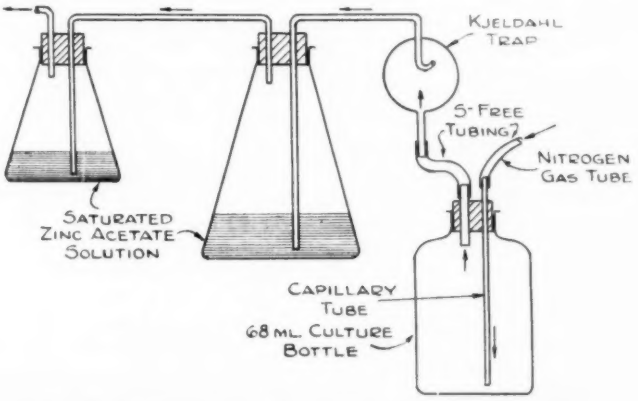


FIGURE 8.—Arrangement of apparatus for H_2S determination.

B. Determination of Dissolved Sulfides

Two types of media were employed in these experiments: one consisting of inorganic substances, the other containing organic compounds. This necessitated two methods of analysis for dissolved sulfides.

1. In an inorganic medium:

(a) Shake culture bottles to insure uniformity of solution.
(b) Take an aliquot portion (10 ml.).
(c) Add to 20 ml. of standard 0.025N solution in a 60 ml. glass-stoppered bottle.
(d) Acidify, shake well and allow to stand 5 minutes.
(e) Titrate with 0.025N sodium thiosulfate solution using a starch indicator.

2. In an organic medium:

(a) Determine hydrogen sulfide as above.
(b) Acidify culture solution with 5 ml. concentrated sulfuric acid. This is done by lifting the stopper of the culture bottle and quickly adding the acid.
(c) Sweep the nitrogen gas and continue as for the determination of hydrogen sulfide above.

C. Determination of Sulfates

Inorganic sulfates were determined by standard gravimetric methods.

Discussion

Although this method is more time-consuming than others, it is especially valuable where small quantities of hydrogen sulfide are to be determined. At no time during the procedure is the system opened to the atmosphere until all the hydrogen sulfide is in a "safe" state. The interference of organic compounds such as skatole and indole is eliminated. Contamination of the absorption solution by the culture medium is eliminated by the use of a Kjeldahl trap. Oxidation of hydrogen sulfide is prevented by prior removal of air by sweeping the entire apparatus with nitrogen gas. The hydrogen sulfide is determined directly.

In the evaluation of the reproducibility of results in using this analytical procedure it was thought that differences in values obtained for hydrogen sulfide and dissolved sulfides in duplicate samples could probably be attributed to an insufficient contact time with nitrogen gas. In order to establish the necessary contact time for introducing nitrogen into the incubation bottle, a series of experiments was performed. The synthetic medium containing only inorganic sources of sulfur was utilized for the production of sulfides by *S. desulfuricans*. Nitrogen was bubbled from the end of the capillary tube at the desired rate of 130 bubbles per minute.

The experiments involved the utilization of various contact times up to 4 hours. Preliminary experiments revealed that consistent results could not be achieved in less than 2 hours. Detailed experiments were performed with nitrogen sweeping times of 2, 3 and 4 hours. After 2 hours the total sulfides seemed to check quite well but a large discrepancy was noted between the hydrogen sulfide and dissolved sulfide determinations in duplicate samples. It was finally established that 4 hours of sweeping time was necessary to secure the degree of accuracy required for the experiments noted in the main portion of this paper.

Statistical Analysis of Reproducibility of Results

Table V presents the results obtained using the nitrogen sweeping technique for 4 hours on synthetic culture media which had been incubated for 42 hours at 37° C. Nine separate incubation bottles were used. The standard deviations and coefficients of variation were determined for hydrogen sulfide and total sulfides.

It will be noted that the results obtained for hydrogen sulfide and total sulfides were very consistent. The coefficient of variation for each was only

TABLE V.—Sulfides Produced in Synthetic Media After 42 Hours' Incubation at 37° C.

Bottle No.	H_2S (p.p.m.)	Dissolved Sulfides (p.p.m.)	Tot. Sulfides (p.p.m.)
1	210	41.4	239
2	221	6.8	215
3	218	34.8	240
4	228	13.2	227
5	220	23.2	230
6	227	14.4	226
7	223	17.2	227
8	224	18.0	228
9	192	28.0	208
Mean	210	—	227
σ_x	10.5	—	9.5
C_v (%)	4.5		4.5

4.5 per cent. Assuming a normal distribution of errors, these statistical results indicate that 95 per cent of the time the analytical procedure can be relied upon to give an experimental error of less than ± 9.0 per cent. The results also signify that 50 per cent of the time the experimental error in any one analysis for H_2S or total sulfides will be within 3 per cent of the mean value which would be obtained from a whole series of similar experiments. Thus, the analytical technique may be relied upon to give a high degree of accuracy in the determination of sulfides and in the subsequent study of the effectiveness of various chemicals in the inhibition of sulfide production by biochemical means.

DISCUSSION

By LeRoy W. Van Kleeck

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Prof. Eliassen has discussed clearly and ably the fundamental principles involved in hydrogen sulfide production. The research he is undertaking on the use of various chlorinated hydrocarbons to control sulfide in sewage is needed and his conclusions will be awaited with interest.

His summation on the inhibitory effects of Cloroben on sulfide production appears a sound basis for further field trials. The writer observed some effects from the use of this material by Guy E. Griffin at Old Greenwich, Conn. in 1935 and 1936. Griffin applied Cloroben at the sewage treatment plant to a stale sewage just prior to plain sedimentation and chlorination in an effort to control odors and reduce the high chlorine demand of the sewage. His results were not published.[1] A dose of 15 p.p.m. was initially tried in the summer of 1935, this being subsequently reduced to 10 p.p.m. because of objectionable odors around the sewage plant from the Cloroben itself. However, the latter dose produced a pronounced odor from the Cloroben and also proved toxic to the process of sludge digestion.[2] Its use was stopped until early in 1936 when a dose of 6 p.p.m. was used. This did not appear to affect digestion, but Cloroben odors persisted around the plant and in the sludge drawn to the drying beds. While the material reduced the sulfides and concurrently resulted in lower chlorine demands, it was concluded that its possible effects on digestion and its penetrating odor outweighed its advantages.

In the light of subsequent field use by Brown, Kennedy and Taylor and the experiments by Eliassen, it appears

[1] The Cloroben used by Griffin was a technical grade of orthodichlorobenzine. It was not prepared, as the present-day Cloroben, as an emulsion.

[2] Not being a Cloroben emulsion, the orthodichlorobenzine probably settled out in the sludge as do the heavy metals toxic to sludge digestion.

that the Cloroben doses used by Griffin in these early trials were too high and were applied too late. A happier ending might have resulted from an initial dose of perhaps 2 p.p.m. to a fresher raw sewage to give a residual in the effluent of around 0.5 p.p.m. However, a warning is in order that when Cloroben is to be added near or at a sewage treatment plant, the possibility of its inherent odor and its accumulative effect on sludge digestion be investigated. To the writer, the penetrating odor of Cloroben as used at Old Greenwich was as objectionable as that of the hydrogen sulfide which it eliminated.

Hydrogen Sulfide from Salt Water

A factor in the reduction of sulfates by sulfur-splitting bacteria normally present in sewage is the presence of salt water. Salt water infiltration into sewers and through leaking tide gates is an ever present possibility in sewer systems located near salt waters. Connecticut has had some examples of this trouble and the problem is a vexatious one.

What is probably a typical analysis of the salts in pure ocean water is presented in Table I. The sulfates present in such waters are readily broken down to sulfides with the production of hydrogen sulfide. Sulfide concentrations as high as 10 p.p.m. have been found in some Connecticut sewages.

In making field tests for sulfides the "Modified Antimony Tartrate Method" as reported by Johnson (1) has been found by the writer to give very dependable results, when used with a home-made color comparator. This comparator should be provided with a yellow paper backing for viewing the samples and standards, and its use has been found necessary for reading H_2S contents below 2 p.p.m. In contrast, the iodine titration method has been found unreliable.

TABLE I.—Salts in Ocean Water

Salt	P.P.M.
Common salt (sodium chloride)	27,213
Magnesium chloride	3,807
Magnesium sulfate	1,658
Gypsum (calcium sulfate)	1,260
Potassium sulfate	863
Calcium carbonate and residue	123
Magnesium bromide	76

An outstanding example of the effect of the breakdown of sulfates introduced into sewage by the entrance of salt water at high tidal stages was reported by Scott and Van Kleeck (2) in tests on the Stanford, Conn. sewage in 1933. Based on extensive tests made in cooperation with the Chlorine Institute, pre-chlorination was adopted, resulting in a reduction of the chlorine demand from 150 lb. per m.g. for post-chlorination to 80 lb. per m.g. with pre-chlorination. Later the source of salt water infiltration was traced to a break between a sanitary sewer and storm drain which permitted the backing up of salt water into the sanitary sewer at every high tide. Since repairing this leak the chlorine demand of this sewage from salt water has further decreased.

The past has taught that operators of sewage works must be ever alert to the harmful effects of this destructive agent—hydrogen sulfide—and must take the necessary steps for its elimination whatever the cause of its formation.

References

1. Johnson, Harry E., "A Comparison of Two Methods for Determination of Hydrogen Sulfide in Sewage." THIS JOURNAL **3**, 205 (April, 1931).

2. Scott, Warren J., and Van Kleeck, L. W., "Chlorine Disinfection of Sewage." THIS JOURNAL, **6**, 784 (July, 1934).

SEWER SYSTEM OPERATION AND MAINTENANCE PROCEDURES AT MILWAUKEE *

By Lloyd D. Knapp

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The Bureau of Sewers designs, constructs, operates and maintains all combined, sanitary and storm sewers in the City of Milwaukee. All house sewers, from the main sewer to the building, are the property and responsibility of the property owner, and must be cleaned and maintained by him. The Milwaukee Sewerage Commission designs, constructs, operates and maintains intercepting sewers and a sewage treatment plant for the entire metropolitan area. The Commission was organized in 1913. Prior to that time all sewers in the City were of the combined type and emptied directly into one of the three rivers or into Lake Michigan.

Since 1915, the city has constructed separate sanitary and storm sewers in its newly annexed territories. Today the Bureau is responsible for approximately 500 miles of combined sewers, 300 miles of sanitary sewers and 300 miles of storm sewers. These sewers, most of which are circular, range in size from 6 in. to 144 in. diameter. Some of the storm sewers are of a rectangular section, the largest of which is a double box, with each side measuring 7 ft. by 10 ft.

The older sewers were built of clay pipe, natural cement concrete pipe and brick. The natural cement concrete pipe sewers were either 12 in. diameter circular, or egg-shaped 12 in. by 18 in., or 15 in. by 21 in., with a flat base to facilitate laying. Most of the older sewers 24 in. diameter or larger were built of brick, and in few instances of planks. Today vitrified clay pipe is used in sizes up to 36 in. diameter, concrete pipe in sizes up to 66 in. diameter, and monolithic concrete for box sections and circular sections as small as 48 in. diameter. Vitrified clay liner plates are used where needed in the monolithic sewers and in pipe sewers 42 in. diameter and over.

It is present policy to use concrete pipe for sanitary and combined sewers in residential and local business areas, and to use vitrified clay pipe in light manufacturing and industrial districts. Zoning is quite well stabilized, and this policy has proven satisfactory over a long period of years. The sewers are quite well ventilated and, since the establishment of the Sewerage Commission, designs have provided for minimum velocities of 2 ft. per second. There are, therefore, but few septic conditions, and there has been no known trouble with hydrogen sulfide gas in the residential areas.

Organization

The Bureau of Sewers is organized into a construction division, an engineering or design division, an accounting division, and a maintenance division. This latter division is in charge of the cleaning, flushing and repair of all sewers and appurtenances, as well as the construction of all catch basins, storm inlets and overflows. The division is under the direct charge of a field supervisor and an assistant. The city is divided into three districts, each under the supervision of a district

* Presented at Twenty-first Annual Meeting, Federation of Sewage Works Associations, Detroit, Mich., October 18–21, 1948.

foreman reporting to the field supervisor. Each district foreman is in charge of two or three construction gangs, consisting of a foreman with eight or ten men, a catch basin cleaning crew, one or two sewer cleaning gangs, a flushing crew, one or two sewer masons with helpers, a troubleman, and a timekeeper. At division headquarters there is a blacksmith, a carpenter, and a machinist, all with helpers, and two sewer examining crews of three men each.

All city-owned automotive equipment, such as automobiles, trucks, trailers, air compressors, eductors, concrete mixers, cranes, etc., are operated and maintained by the Bureau of Municipal Equipment. This equipment is rented to the various other bureaus as needed and at rates somewhat below that charged by private owners. Special equipment such as pumps, cleaning machines, steamers, etc. are in direct charge of the Bureau of Sewers.

Construction Crews

The construction crews excavate for the catch basins, and construct storm inlets and overflows during the construction seasons. These crews also build short sections of new sewers as the occasion may require.

Catch basin and manhole bottoms are poured with ready-mixed concrete and, where conditions permit, steel forms are set up and the bottom half of the catch basin is also poured with ready-mixed concrete. A sandbag is placed in the form to provide an opening for the overflow pipe and trap. A sewer mason follows this crew and lays up the top half of the catch basin with concrete brick.

The storm inlet assembly consists of a frame and grate with a side inlet box resting on a layer of brick. The brick rests on the edge of a large cast iron bowl, and the bowl in turn rests on a cast iron elbow with a 15-in. radius. The elbow has a large flat base to facilitate placement, and after it has been set and backfilled with gravel, the rest of the assembly is quickly put together. The frames, grates, and side inlet boxes used in storm inlet construction are identical with the castings used for catch basins.

Each crew has a combination tool wagon and shanty equipped with a small stove. Each crew is assigned an air compressor with sufficient capacity to operate two jack hammers continuously. The city owns both trailer-mounted and truck-mounted compressors and an effort is made to keep one truck-mounted compressor in each district for emergency use. The older compressors are mostly Sullivan or Ingersoll Rand, while the newer machines are LeRoi. Each crew also has two jack hammers, two clay diggers, and a demolition tool. This latter tool is a small compact rig that can be used inside a catch basin or manhole for tearing out masonry work. These pneumatic tools are of various makes such as Sullivan, Cleveland, Ingersoll Rand, and Chicago Pneumatic. All of the pneumatic equipment has proven satisfactory.

Each construction crew also has a 1½-in. C. H. & E. centrifugal pump, two wheelbarrows, screw jacks, 200 ft. of 2½-in. flushing hose, 100 ft. of 1-in. flushing hose, a hydrant valve, barricades, red flags, lanterns, and miscellaneous small tools. These special hydrant valves are used to regulate the flow of water, thus permitting the hydrant itself to be open to full capacity. The Water Department recommends this practice as a means of preventing wear and tear on the hydrant parts.

The city owns one truck-mounted Hydro-crane (Figure 1) with a ¼-cu. yd. bucket, which the Bureau of Sewers uses on a year-around basis. One or two more of these cranes are rented during the construction season. These cranes are operated hydraulically, even to the opening and closing of the bucket. They are used for dig-

ging purposes, and they operate quite successfully where the ground is not too hard.

The advantages of this type of machine are that it can be quickly moved from place to place in an emergency and can be digging 2 or 3 minutes after arrival on the job. The machine is mounted on an International Truck chassis and can travel along city streets safely at a speed of 25 to 30 miles per hour. This equipment is used to greatest advantage in the outskirts where there is little interference from other underground structures. One 2½-cu. yd. dump truck accompanies each Hydro-crane. This is sufficient, especially in the outskirts where a dump can usually be found within a 5- or 10-minute run. These cranes are also used in the older sections of the city, at locations where digging conditions are favorable. Experience with the Hydro-cranes to date indicates that under favorable conditions the cost of excavation can be reduced approximately 30 per cent over hand digging.

Otherwise all digging for catch basin and overflow construction as well as for sewer repairs is done by hand. The hand digging crews load their dirt into trailers of about 5 cu. yd. capacity. The empties are spotted and loads pulled once a day.

In the winter months the construction crews are put out on repair jobs. They remove and replace broken or cracked pipe, break out and replace defective concrete in tunnels, and break out defective masonry in the brick sewers preparatory to repairs to be made by the sewer masons. One extensive repair job carried over several winter seasons, involving the removal and replacement of concrete in the lower quadrant of a 72-in. tunnel and the lining of same with vitrified clay liner plates. This was a storm sewer tunnel into which acid had been discharged for several years. Winter digging is admittedly expensive, but it has been necessary to operate all winter in order to keep the crews manned with experienced men, and because it

FIGURE 1.—Milwaukee's Hydro-crane set up for digging operation.

is not possible to hire sufficient men to make the necessary repairs in the summer months when the construction program is heavy. Then too, it would be difficult to secure the extra tools and equipment needed to do both repairs and construction in the summer.

The city of Milwaukee for years has had an Accident Prevention Committee composed of key representatives of the various operating departments. The field supervisor is the representative for the Bureau. This committee has done much to promote safety among city employees. Supervisory forces make it a point to instruct new men in the use of tools, to examine tools for defects, etc. Supervisors are especially particular in the bracing and shoring of trenches and tunnel sections. Men are not permitted to work in the so-called "rat hole" sections. As a result of these precautions the usual accidents are of a minor nature. There have been no accidents due to caveins for many years.

Sewer Cleaning

There are four sewer cleaning crews of three men each. One crew is using a pair of Champion 7.5-h.p. machines; while two crews are using a pair of Sewer Turbine 7.5-h.p. machines. One crew has a pair of 3-h.p. Sewer Turbine machines. The smaller machines are used on the smaller sewers so as not to overload the motors. All of the machines are proving satisfactory. However, the level winding apparatus was removed from the Champion machines and substituted by a loose pulley. The gearing on the Turbine machines was also changed so as to increase the cable speed from 33 to 90 ft. per minute. Self-closing buckets are used in sizes from 6 in. to 18 in., made by the Champion Company. Some plain buckets or scoops have been made up to fit several different sizes of small egg-shaped sewers, and circular scoops have been made for sewers 21 in. diameter or larger.

Elm strips ½ in. by 2 in. and of varying lengths up to 10 or 12 ft. are used in getting the pilot cables through the sewer. These strips are notched at the ends and fastened together with wire. They are quite flexible and can be readily shoved through the sewer. Any water in the sewer, of course, will cause the strips to float and facilitates their use. If the normal flow in the sewer is not sufficient to float the strips it is an easy matter to connect a hose to the nearest hydrant and obtain the amount of water desired. Jointed, wooden sewer rods about 1½ in. square and in 3-ft. lengths are used for the same purpose. When neither the elm strips or rods will work, a Flexible sewer rod is put through and the pilot cable pulled back when the rod is withdrawn.

Sewers under busy streets or car tracks are cleaned at night. When cleaning along car tracks, hand cleaning rigs are employed, as these can be shoved aside more readily than the power machines in order to let street cars pass.

Flushing

Four flushing crews of three men each are maintained. Each crew is equipped with about 500 ft. of 2½-in. hose, one 8-in. and one 12-in. flushing bag, a wheelbarrow, manhole guards and various small tools. During the winter a stiff rubber coated hose is used, from which the water can be drained and which will not freeze up during severe cold. In the warmer months discarded fire hose is employed, which is bought from the Fire Department for 10 cents a foot. One length of the rubber covered hose is shoved down the manhole and into the sewer because of ease of handling. Hose bridges are made by a carpenter and consist of chamfered 3-in. planks fastened together with steel bands. Discarded rubber hose is cut up and nailed on the bottom of the planks and this prevents skidding of the hose

bridge under impact of even heavy vehicles, provided they travel at moderate speed. During 1947, 262 miles of sewers were flushed.

All storm inlets are flushed once a year by these same crews. There is a considerable waste of time in coupling up hose to the nearest hydrant, setting the hose bridges, etc., only to find that one good shot of water is all that is needed. The field supervisor is now studying the possibilities of using power flushers for this work.

Catch Basin Cleaning

Catch basins are cleaned once a year. This work is carried out by two catch basin cleaning crews, each consisting of a foreman and eight to ten men. Each crew has three or four Elgin eductors, a 1½-ton truck, a wheelbarrow, a small centrifugal pump and various miscellaneous tools. Each eductor crew will clean an average of twenty catch basins per day. The truck and two men are used to clean, by hand, those basins which are inaccessible to the eductors, and to finish cleaning those basins which cannot be properly cleaned by the eductors. Each eductor crew carries a garden rake for removing sticks, branches, etc. They frequently find chunks of broken concrete or other material which cannot be removed either by the eductor or by the rake, and the extra cleaning is then taken care of by this manual cleaning gang. The eductors are over 20 years old and are in need of replacement. It is hoped soon to inaugurate a program of modern equipment replacements.

The eductors operate about 8 months of the year, which is about all that weather conditions will permit. During the winter months the crews do hand cleaning of catch basins.

Last year 19,262 catch basins were cleaned by eductor and 5,099 by hand. Admittedly hand cleaning is more expensive ; there will always be many catch basins that cannot be cleaned with the present equipment. And, invariably, either weather conditions or appropriations for equipment rental will interfere before the complete rounds can be made of all catch basin cleaning work. There are approximately 25,000 catch basins and 15,000 storm inlets. The inlets are taken care of, as previously mentioned, by the flushing crews.

The foreman is furnished with blue line prints of quarter-sections showing the location of all catch basins and storm inlets. He returns these maps to headquarters showing the date of cleaning and notes as to the structural condition of the basins.

Sewer Troublemen

Each district has a sewer troubleman who drives a pick-up truck. His duty is to investigate all complaints in his district. These complaints cover a wide range of subjects, from water standing in the gutter to a leaking kitchen faucet; from rats crawling out of plumbing fixtures to rubber balls lodged in downspouts. In most cases the Bureau of Sewers is not involved, but the troubleman will give the best advice of which he is capable.

The troubleman opens up blocked sewers and catch basins, calling on the nearest labor gang for help. A troubleman and two laborers are on duty every Saturday, Sunday and holiday to handle emergency calls and one of the troublemen is always subject to call by the City Hall night complaint clerk.

During storms, when hundreds of complaints may come in, various foremen and some of the better class laborers are used on trouble shooting service. At such times the maximum number of crews are operated that can be provided with transportation. These forces stay on the job until every complaint has been investigated. In some instances this has taken as many as 36 hours of continuous operation.

Troublemen are also employed dur-

ing slack periods with the delivery of small orders of materials for construction crews and the moving of the flushing crews and brickmasons from job to job. They also answer complaints on loose manhole covers. If the cover and frame are found to be in reasonably good condition the cover is sealed in place with Hallemite, which has been giving us good service. All flushing crews carry a small supply of this compound.

Sewer Inspection Crews

There are two sewer examining crews consisting of a foreman and two men each. These crews have trained personnel and special equipment, and have regular programs for examining sewers as to structural conditions, amount of flow, depth of deposit, etc. Many sewers are flushed or cleaned in accordance with the information obtained from these reports. When a street is to be repaved, an examining crew inspects the sewers, and the designers use their report to determine the necessity of rebuilding the sewer because of its structural condition.

These crews are used for many types of work. They examine all contract work, upon completion, and discover many defects overlooked by the inspector, or which could not be determined by the inspector working alone. They are used frequently in tracing out the point at which given house services and overflows are connected to the sewer. They check for highwater marks in manholes following storms, and occasionally they make house to house surveys to determine the extent of backwater conditions.

These crews are so valuable that their services are in constant demand by the construction forces, engineering division and also by district foremen. It is difficult to keep them at their primary task of examining sewers on a routine basis.

Examinations of the smaller sewers are made by means of flashlights and mirrors. The men crawl or walk through all sewers 30 in. in diameter or larger, flow conditions permitting, and occasionally crawl through 24-in. sewers.

Each crew has a safety belt for use in deep manholes, rubber coats, hats and boots for ordinary work and rubber suits for very wet, dirty work. They also carry a Wolff safety lamp, aluminum ladders for use where manhole steps are unsafe or missing, a small quantity of potassium permanganate, and a considerable number of small tools and supplies.

Sewer Masons

There are four sewer masons, each with two helpers, who work the year around. During the construction season, when the new catch basin work required in connection with new paving is the heaviest, two or three more mason crews are added to build basins and to set basins and manhole frames to final grade. Because of past budget restrictions it has been necessary to impose on some of the more skilled laborers to do this work without extra pay. This past summer, however, it was possible to obtain for three of the best men the regular sewer mason pay for a period of a few months. A plan is now in development to pay four of the best men a rate $15 per month above that of common labor. These men will be used normally as leading helpers to a sewer mason. In the rush seasons they will be used for setting manholes and catch basins to grade, thus relieving the regular masons for the more skilled work of building manholes and catch basins.

There are more brick repairs than can be handled with the four regular masons during the off season. There are perhaps 25,000 catch basins and approximately 40,000 manholes, most of which are built of brick and many of which need repairs, as well as many, many miles of brick sewers which need more and more repair work

as they become older.

At the present time the mason crews have only a small tool box, but a program is planned to equip all crews with a small combination tool wagon and shanty.

Yards

At the district yards there is a supply of special tools and equipment as needed, such as centrifugal pumps up to 4-in. discharge, 4-in. Pemberthy syphon pumps, three Homelite blowers operated by gas engines, two electrically operated blowers, three 1500-watt portable light plants, and a Cleaver Brooks oil-burning steamer for thawing out frozen catch basins. There are small derricks and two hoists operated by compressed air and two operated by gas engines, also flumes of various sizes, rock drills, and cutting and welding equipment. In addition there are three Flexible sewer rod outfits which are used in opening up blocked sewers, and Coleman rods for use in checking clogged house sewers.

The clerical forces keep time and material records, order materials and equipment, keep a card index file of complaints by house numbers, type the reports of the examining crews, tabulate the records of cleaning, flushing, etc. Ready-mix concrete, backfill gravel, brick and pipe are purchased on open order and may be secured as needed from the vendor, who delivers directly to the job.

In all there are 160 people in the operation and repair division, which includes all classes from laborers and clerks on up to the field supervisor. Common laborers are known as "city laborers" and do sewer cleaning and flushing and catch basin cleaning. They receive a top pay of $140 per month, plus a cost of living bonus of $83.02 per month. The laborers on construction crews are called "sewer laborers" and receive a top pay of $150 per month, plus the cost of living bonus. Sewer examiners get $165 per month, their foreman and the troublemen get $180 per month, while the construction crew foremen receive $210 per month, all with the cost of living bonus in addition. The highest, of course, is received by the field supervisor, who gets $350 per month and the bonus. The total budget for operation and repairs for 1948 amounted to $529,459, approximately $480 per mile.

DISCUSSION

By Francis S. Friel

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Mr. Knapp has given an excellent outline of the scope of the organization, equipment and maintenance procedures of the Milwaukee Bureau of Sewers.

In Mr. Knapp's remarks relating to sewer construction he reports that all house sewers from the main sewer to the building are the responsibility of the property owner and must be cleaned and maintained by him. This same practice prevails in the Philadelphia area. Prior to the war, one suburban area outside of Philadelphia made house connections through contract, within the bed of the street, and charged the property owners a fixed sum for it. This practice has been stopped because of present labor conditions, and now property owners are required to engage their own contractors who, in turn, must be bonded by the municipality.

Reference is made to the practice in Milwaukee of using vitrified clay pipe for sewer lines up to 36 in. in diameter; concrete pipe up to 66 in. in diameter and monolithic concrete struc-

tures with vitrified clay liner plates where needed. It is also interesting to observe that it is the policy in Milwaukee to use concrete pipe for sanitary and combined sewers in residential and local business areas, and to use vitrified clay pipe in light manufacturing and industrial districts. This practice is commended.

Mr. Knapp does not mention any difficulty experienced in locating manholes or other sewer structures. Manholes are often covered with new paving or by grading of private property or regrading of roads, and instruments to locate them are invaluable in time-saving. Magnetic dip needles are convenient for shallow depths, while the "M-scope" is required for deeper coverage.

The use of the sewer examining crews for inspection of new construction and for periodic examination of lines is good practice. The best insurance against excessive maintenance is a well-designed and well-constructed sewer line. A small municipality in Pennsylvania installed a sewer system about 25 years ago. The sewers were poorly constructed due to a lack of proper inspection. Since the original construction, more than twice the first cost has been spent by the town and by W.P.A. in attempting to repair the sewer lines. In some instances, a pipe between two manholes, located less than 300 ft. apart, was out of alignment as much as 3 feet. In addition, the system leaked badly. The unsatisfactory conditions in this sanitary sewer system have not been corrected and a large expenditure is still necessary to complete the rectification of the original unsatisfactory work. Money spent for good engineering and inspection pays dividends on future maintenance.

The disintegration of sewers, as indicated by the need for a retreading job on a 72-in. sewer noted in Mr. Knapp's paper, once again illustrates the need and justification for regulation of the disposal of industrial wastes, taking into account the character as well as the volume of the wastes to be handled. In some cities, surveys have been made to eliminate the discharge of industrial wastes, particularly strong acids, which might cause the disintegration of sewer lines. It is certainly logical to require a particular industry to neutralize strong wastes prior to their discharge to a sewer system.

The frequency of cleaning of a sewer line is dictated by the character of sewage, the flatness of the sewer grades, the condition of the pipes themselves and also possibly by weather and climatic conditions. No hard and fast rule can be applied as to the interval between the cleaning of a sewer. In Lower Merion Township, Pa., the sewers are flushed once a year. The conditions observed during the flushing period form the basis of a priority maintenance program. All free time of the maintenance crew is used in a systematic cleaning of the 142 miles of sewers. Six years are required for the complete coverage cycle. A force of four men with one truck and up-to-date cleaning equipment does the job. The superintendent reported recently that only three stoppage complaints have been received in five years.

There are some instances where sewers have never been cleaned since they were installed. On the other hand, certain sewers have clogged in a relatively short period of time due to the growth of tree roots and other external causes.

The use of a flexible steel type of sewer rod to clean sewers has proved advantageous in many places throughout the country. This type of equipment may be used to remove obstructions which cannot be dislodged by a wooden rod. It is especially effective where fire plugs may not be available and when extra flushing water must be hauled to the work. There also is a safety factor involved in using flexible

steel rods, since the men are working above ground.

The mechanical cleaning at Milwaukee is apparently by the drag-line type of cleaner. This type of apparatus is effective but is inclined to cut tracks in deposits where flows are small. The water-driven turbine type will do its work well, but the writer does not believe that this latter type of equipment is equal to the revolving spring-steel rod utilizing different kinds of cleaning or cutting heads, and the rubber cups for removing sand or other deposits when backed by a head of sewage.

Flexible sewer rods and machines were found to be valuable cleaners at Boston (*American City*, August, 1942). At Los Angeles, Brown states that nearly one and one-half million feet of sewer lines are cleaned each year with three machines, and the cost of upkeep and personnel was 3½ cents per foot of sewer pipe cleaned. Mr. Brown states that each machine may be set up at 10 to 20 locations a day and can clean from 1500 to 2500 ft. of sewer line daily (*Water and Sewage Works*, p. 249, 1947).

Catch basins at Milwaukee are cleaned once each year. This practice varies throughout the country. In some places they are cleaned as often as once every 3 months, while in other instances the period of cleaning is extended to about once in 3 years, as in Boston. The eductor type of catch basin cleaning apparatus as mentioned for Milwaukee is most effective, and reduces the unit cost for the removal of grit and other foreign material.

In most municipalities, where the water works is owned by the city, there is no problem in securing water for flushing sewers, but where a private company owns the water works, the problem differs materially. Again citing the case of Lower Merion Township, it is cheaper to use creek water for flushing than to purchase water from the private utility. The township, which has an area of 24 sq. mi., has a 700-gal. tank mounted upon a 2½-ton truck, and water is pumped to this tank from a series of creeks or taken from one of the twelve fire hydrants permitted to be used. The tank is equipped with a quick-opening valve, and the contents are discharged rapidly to a manhole for flushing.

SEWER SERVICE CHARGES

In pointing out that sewer service charges must be based not only on use of the sewers, but also on "readiness to use," Henry W. Taylor, New York City consulting engineer, compares the latter factor with the fire protection charge used in water rates. Mr. Taylor's discussion, presented at a recent meeting of the New York-New Jersey Chapter of the American Public Works Association, lists certain formulas used to determine an equitable charge for industrial wastes and tabulates the sewer service charges in use throughout the New York area.

Mimeographed copies of the 27-page paper are available at a cost of $0.50 from W. S. Foster, Secretary, c/o American City Magazine, 470 Fourth Avenue, New York 16, N. Y.

COLIFORM DEATH RATES RESULTING FROM CHLORINATION OF RAW SEWAGE

By H. A. Wyckoff

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The use of chlorine in the treatment of sewage has been under study for over 30 years, and the value of such chlorine usage for certain specified objectives has long been well established. The work of Mohlman (1) in 1929 and Baity (2) in 1933 showed the effectiveness of chlorine on the reduction of B.O.D., and many subsequent reports have confirmed these early studies. Symons (3) has shown the effectiveness of chlorine in reducing the coliform content of streams receiving sewage, while Rawn (4) has indicated the value of chlorination in the control of odor and septicity. Numerous reports have been made on various other uses of chlorine in sewage treatment, such as grease removal, control of sludge bulking, etc. As Faber (5) states: "Chlorination is represented in sewage literature mainly by reports on operation and by operating results."

In order to obtain additional data on the rate of bacterial (coliform) kill in plant-scale chlorination of raw sewage at varying chlorine residuals and for various contact periods, a research project was initiated. This paper reports the results obtained.

Experimental Procedure

The Egan sewage treatment plant of Atlanta, Georgia, was employed in these experiments. This plant includes rectangular primary settling basins, rotary type trickling filters, secondary settling basins, separate sludge digestion tanks, and open sludge drying beds. The sewage entering this plant is almost completely domestic sewage. Since considerable storm water also enters during periods of heavy rain, testing was avoided at such times. The characteristics of the sewage, as determined on samples taken at the time the experiments were made, are shown in Table I.

TABLE I.—Characteristics of Raw Sewage as Determined from Samples Taken at Time of Individual Runs

	pH	Suspended Solids (p.p.m.)	B.O.D. (p.p.m.)	Chlorine Demand (p.p.m.)	M.P.N.
Minimum	6.8	255	223	4.0	230,000
Maximum	7.6	506	433	9.0	9,500,000
Mean	7.1	404	305	6.4	2,130,000

In preparation for the tests, a Wallace & Tiernan chlorinator was installed beside the bar screen, the chlorine entering the sewage behind the bar screen and immediately in front of the Parshall flume. Before each run, the chlorinator was set to deliver the dosage desired for that particular run. The entering sewage passed the Parshall flume, went through 15 ft. of conduit to a square manhole where it made a right-angle turn, and then passed through 15 ft. of conduit to a flume where it divided and entered the settling basins. This passage consumed about 0.5 minute of time, which proved sufficient for adequate mixing of the chlorine with the sewage.

A sample of the chlorinated sewage was caught just before it entered the

primary settling basin and was distributed in five sterile sample bottles labeled, respectively, "1-minute," "5-minute," "15-minute," "30-minute," and "60-minute." At this same time, a sample of the raw sewage was taken just behind the bar screen and ahead of the chlorine entrance. The chlorine residual was then determined immediately on the "1-minute" bottle, and sterile sodium thiosulfate solution was added to dechlorinate. This was indicated as the "1-minute" sample. At the end of five minutes, the residual was determined on the "5-minute" bottle, and the sample dechlorinated. At the end of the respective contact periods, the other bottles were similarly treated. All six samples were then carried through serial dilutions, planted in lactose tubes, and the Most Probable Number per ml. (M.P.N.) (presumptive) determined. The pH and the chlorine demand (10-minute) were determined on the unchlorinated sample, and B.O.D. and suspended solids were determined on occasional samples.

All determinations were made according to *Standard Methods for the Examination of Water and Sewage* (10). In determining the chlorine residuals, the ortho-tolidine test with Hellige comparators was used.

TABLE II.—Typical Data Collected During Individual Experiments

Experiment No. 4

Sewage flow 800,000 g.p.d.; pH (raw) 7.2; chlorine demand 8.9

Contact Period		Raw	1 min.	5 min.	15 min.	30 min.	60 min.
Chlorine Residual (p.p.m.)	flash	—	0.2	0.1	0.1	0.05	>0.05
	max.	—	0.3	0.15	0.1	0.1	>0.05
	5-min.	—	0.05	0.05	0.05	0.0	0.0
M.P.N. per ml.		2,400,000	2,400,000	240	240	24	62

Experiment No. 25

Sewage flow 950,000 g.p.d.; pH (raw) 7.2; chlorine demand 6.0

Contact Period		Raw	1 min.	5 min.	15 min.	30 min.	60 min.
Chlorine Residual (p.p.m.)	flash	—	0.3	0.2	0.15	0.2	0.1
	max.	—	0.9	0.9	0.2	0.2	0.1
	5-min.	—	0.8	0.8	0.15	0.15	0.0
M.P.N. per ml.		620,000	1,300	1,300	2,400	2,400	620

Experiment No. 40

Sewage flow 1,100,000 g.p.d.; pH (raw) 7.0; chlorine demand 4.8

Contact Period		Raw	1 min.	5 min.	15 min.	30 min.	60 min.
Chlorine Residual (p.p.m.)	flash	—	0.5	0.5	0.5	0.3	0.3
	max.	—	5.0	4.0	3.0	2.0	1.8
	5-min.	—	5.0	3.0	2.0	2.0	1.8
M.P.N. per ml.		230,000	23,000	230	230	230	230

TABLE III (a).—M.P.N. per ml. After Various Contact Periods When Chlorine Residuals were >0.0 and <0.5 p.p.m.

Exp. No.	Raw	1 min.	5 min.	15 min.	30 min.	60 min.
2	620,000	2,400,000	620	2,400	240	62
3	2,000,000	5,000,000	230	1,300	240	62
4	2,400,000	2,400,000	240	240	24	62
6	230,000	62,000	130	240	620	23
8	5,000,000	2,300,000	6,200	2,300	240,000	24,000
10	6,200,000	6,200,000	2,400	2,100	620	620
11	9,500,000	13,000,000	700,000	6,200	6,200	2,300
12	2,400,000	60,000	62	130	280	750
13	6,200,000	2,400,000	240,000	1,300	2,100	4,300
14	620,000	2,400,000	620	130	230	2,300
15	620,000	46,000	620	620	500	1,300
17	2,400,000	2,400,000	130,000	620	240	2,100
18	2,300,000	2,300,000	2,300,000	95,000	6,200	620
43	6,200,000	230,000	6,200	2,300	6,200	2,300
Mean	3,350,000	2,770,000	240,000	8,200	18,840	2,910
Median	2,400,000	2,400,000	1,500	1,300	560	2,000
Kill (%)	—	0	99.9	99.9	99.9	99.9

TABLE III (b).—M.P.N. per ml. After Various Contact Periods When Chlorine Residuals were >0.49 and <1.0 p.p.m.

Exp. No.	Raw	1 min.	5 min.	15 min.	30 min.	60 min.
1	2,400,000	620,000	230	23	23	62
5	5,000,000	620,000	120	620	62	50
7	2,100,000	2,400,000	120	230	23	23
9	6,200,000	23,000	60	13	62	62
19	7,000,000	290,000	94,000	94,000	24,000	70,000
25	620,000	1,300	1,300	2,400	2,400	620
47	620,000	230,000	—	62,000	13,000	2,300
52	2,400,000	23,000	6,200	2,300	2,100	950
Mean	3,290,000	523,000	14,000	20,000	5,200	9,300
Median	2,400,000	230,000	230	1,500	1,400	620
Kill (%)	—	90.4	99.9	99.9	99.9	99.9

TABLE III (c).—M.P.N. per ml. After Various Contact Periods When Chlorine Residuals were >0.99 and <2.0 p.p.m.

Exp. No.	Raw	1 min.	5 min.	15 min.	30 min.	60 min.
26	620,000	620	1,300	240	230	620
36	620,000	130,000	2,300	6,200	600	6,200
37	2,400,000	230,000	2,300	2,300	1,300	24,000
46	1,200,000	230,000	—	60	620	230
Mean	1,200,000	147,000	1,900	2,200	690	7,700
Median	900,000	180,000	2,300	1,400	600	2,000
Kill (%)	—	80.0	99.7	99.8	99.9	99.8

Discussion

Table II contains samples of data collected during individual runs, and these data are reassembled in groups, according to the initial chlorine residual ranges, in Table III. Flash, maximum, and 5-minute color intensities were recorded in the determinations of the chlorine residual. As indicated in Table II, the flash intensity was consistently less than 1 p.p.m., values gradually building up to a maximum

TABLE III (d).—M.P.N. per ml. After Various Contact Periods When Chlorine Residuals were >1.99 and <3.0 p.p.m.

Exp. No.	Raw	1 min.	5 min.	15 min.	30 min.	60 min.
29	620,000	230	62	240	23	62
30	6,200,000	6,200	240	240	24	62
31	2,300,000	240,000	230	62	240	24
44	500,000	23,000	600	23,000	2,300	13,000
53	620,000	2,300	230	230	60	130
Mean	2,050,000	54,000	270	4,700	530	2,600
Median	620,000	6,200	230	240	60	60
Kill (%)	—	99.0	99.9	99.9	99.9	99.9

TABLE III (e).—M.P.N. per ml. After Various Contact Periods When Chlorine Residuals were >2.99 and <4.0 p.p.m.

Exp. No.	Raw	1 min.	5 min.	15 min.	30 min.	60 min.
21	1,300,000	6,200	230	2,400	13	23
23	500,000	6,200,000	240	240	70	13
32	1,300,000	23,000	23,000	230	62	240
34	230,000	62,000	6,200	1,300	2,400	6,200
39	620,000	23,000	1,300	6,200	620	62
50	620,000	12,000	230	230	23	62
Mean	760,000	155,000	5,200	1,800	550	1,100
Median	620,000	23,000	750	750	70	60
Kill (%)	—	96.3	99.8	99.8	99.9	99.9

TABLE III (f).—M.P.N. per ml. After Various Contact Periods When Chlorine Residuals were >3.99 and <5.0 p.p.m.

Exp. No.	Raw	1 min.	5 min.	15 min.	30 min.	60 min.
22	620,000	2,300	7,000	210	700	700
33	6,200,000	620	230	230	62	62
35	2,400,000	62,000	230	620	13	6,200
38	620,000	62,000	23,000	2,300	6,200	60
45	230,000	4,600	1,300	620	2,300	620
48	620,000	—	230	23	62	620
51	500,000	2,300	620	230	620	62
Mean	1,600,000	22,000	4,700	600	1,400	1,200
Median	620,000	3,500	620	230	620	620
Kill (%)	—	99.4	99.9	99.9	99.9	99.9

TABLE III (g).—M.P.N. per ml. After Various Contact Periods When Chlorine Residuals were >4.99 and <6.5 p.p.m.

Exp. No.	Raw	1 min.	5 min.	15 min.	30 min.	60 min.
40	230,000	23,000	230	230	230	230
41	2,400,000	62,000	2,300	230	620	620
42	230,000	6,200	620	2,400	230	230
49	620,000	23,000	210	230	6	6
Mean	870,000	28,500	850	750	275	270
Median	425,000	23,000	425	230	230	230
Kill (%)	—	94.6	99.9	99.9	99.9	99.9

intensity, which was reached in about 3 minutes, then subsiding somewhat to the 5-minute intensity. In Table III, the maximum intensity is recorded as the chlorine residual.

Rudolfs (6) has called attention to the "instantaneous" high bacterial kill when only 20, 40, and 50 per cent of the initial chlorine demand of the sewage is satisfied. In these experiments, when the initial residual ranged between 0.0 and 0.5 p.p.m., the medial bacterial reduction in one minute was insignificant; however, when the initial residual was greater than 0.5 and less than 2.0 p.p.m., an 80 to 90 per cent kill was accomplished within one minute. The median kill in the various residual ranges, as indicated in Table III, exceeded 99 per cent in all cases after 5 minutes of contact time, and after only one minute in runs made with over 2.0 p.p.m. residual. Survival numbers continued to decrease through the 15-minute and 30-minute periods of contact, but there was no significant decrease in survival numbers in the last 30 minutes of the 60-minute contact period. In a majority of the tests, the M.P.N. remained the same as for the 30-minute period, or actually increased, in spite of the fact that there was usually a definite residual at the end of 60 minutes. It seems significant that while there was a definite increase in the bacterial death rate within the first minute of chlorine contact accompanying increasing chlorine residuals, the increase in death rate after one minute of contact accompanying increasing chlorine residuals was quite small.

The relatively slight increase in the bacterial killing power resulting from fairly large increases in the chlorine residuals of the sewage is in agreement with the theoretical concept of chlorine disinfection held by Schmelkes (7). This concept states that the rate of bacterial death from chlorine, or those of its derivatives which are oxidants, will be dependent upon the oxidation potential of the solution in which the bacteria are suspended. In raw sewage, there is a high concentration of ammonia (reductant) in relation to the concentration of the chloramine (oxidant). From the equation for calculating the potential developed from the ratio of the concentrations of the oxidant and the reductant, $E = E_o - \log (NH_3 \times HOCl/NH_2Cl)$, it is evident that changes in the chloramine concentration from 0.05 to 6.0 p.p.m (0.01 to 0.2 milli-equivalents) will cause very little change in the potential developed in the presence of 28.0 p.p.m (2.0 milli-equivalents) of ammonia (the average original ammonia content of the sewage). Experimental evidence that the change in potential developed with increasing chloramine concentrations is not large, is shown by Moore, Megregian, and Ruchhoft (8) and has been confirmed in this laboratory. It is also evident

that, with ammonia as the reductant, the chloramine-to-ammonia ratio is always greater than one under the conditions of this work, and that the chlorine-sewage solution will never quite attain the E_0 in the equation for the ammonia-chloramine system.

In view of the complex nature of sewage, it is quite probable that there may be present reducing substances other than ammonia, such as proteins and their derivatives, whose oxidation potential systems will have a lower E_0 (that is, a higher reducing potential) than the chloramine-ammonia system. However, compared with the amount of ammonia present, the proteins are present in very low concentrations. The lower E_0 of the chloroprotein would be indicated by a slower rate of color development from the chloroprotein-ortho-tolidine system than from the chloramine-ortho-tolidine system.

The rate of color development noted with the higher chlorine residuals indicates the presence of a chlorine compound, such as chloramine, having an oxidation potential slightly higher than that of ortho-tolidine. The reduction of the color intensity after several minutes of contact in the lower chlorine residual values indicates that a small amount of oxidizable substances remains in the chlorinated sewage, even after a 30- to 60-minute contact period. The oxidizable substances remaining were evidently not oxidized by the chloramine at the pH of the sewage-chlorine (chloramine) solution, but were oxidized by the chlorine because of the higher oxidation potential of the chlorine in the solution at the lower pH induced by the addition of the ortho-tolidine reagent.

In order to increase materially the rate of bacterial kill in sewage, it would be necessary, according to the oxidation-potential concept of disinfection, either to increase very greatly the chloramine concentration or to use a system with a higher E_0 at the same chlorine residual. In water treatment, this latter method is accomplished by chlorination to a residual value beyond the breakpoint. However, since breakpoint values for sewage require extremely large amounts of chlorine (9), it is not likely that breakpoint chlorination of raw sewage will be practiced. No doubt there would be a continuing higher rate of bacterial kill as the chloramine concentration is increased appreciably above 6 p.p.m. (the highest concentration used in these experiments), since the system will still be approaching an equivalent concentration of the oxidant (chloramine) and the reductant (ammonia). However, it would also be anticipated that the ratio of increase in kill will continue low in proportion to the increase in residual.

Summary

The numbers of coliform organisms surviving in raw sewage after exposure to chlorine residuals from 0.05 to 6.0 p.p.m. for chlorine contact periods of 1, 5, 15, 30, and 60 minutes were determined. When the initial chlorine residual was less than 0.5 p.p.m., the medial bacterial kill in one minute was not significant. However, when the initial chlorine residual was greater than 0.5 p.p.m., the medial bacterial kill after one minute's chlorine contact was 80 per cent or greater, increasing with the increase in chlorine residual. After 5 minutes of chlorine contact the bacterial kill reached a median of over 99 per cent in all chlorine-residual ranges tested.

While the survival numbers decreased during 15 and 30 minutes of chlorine contact, the decrease was not great, and there was no significant decrease after 30 minutes. After one minute of chlorine contact, the increase in bacterial kill, in relation to the increase in chlorine residual, was insignificant. These results seem to be in agreement with the oxidation-potential concept of chlorine disinfection.

Acknowledgments

The author acknowledges with appreciation the cooperation of Mr. Clark Donaldson, Chief of Construction, city of Atlanta, and Mr. M. B. Nixon, Engineer of Sewers, city of Atlanta, in making the Egan treatment plant available for these experiments. Special mention should also be made of the assistance of Dr. R. S. Ingols, Research Associate Professor of Chemistry, Georgia Institute of Technology. The financial assistance of the Wallace and Tiernan Company, which made this work possible, is gratefully appreciated. The chlorine used in this work was furnished gratis by the Pittsburgh Plate Glass Company.

References

1. Mohlman, W. L., Hurwitz, E., and Ruchhoft, C. C., "The Chlorination of Sewage and Effluents." *Proc. Eleventh Texas Water Works Short School* (January, 1929).
2. Baity, H. G., Merryfield, F., and Uzzle, A. B., "Some Effects of Chlorination Upon the Receiving Stream." THIS JOURNAL, **5**, 3, 429 (May, 1933).
3. Symons, G. E., Velzy, C. R., and Johnson, J. W., "Third Year of Sewage Treatment Operation at Buffalo, N. Y." *Public Works*, **73**, 1, 27 (1942).
4. Rawn, A. M., "Sewage Flows and Composition Affecting Treatment." THIS JOURNAL, **13**, 1, 66 (January, 1941).
5. Faber, H. A., "The Chlorination of Sewage and Industrial Waste." THIS JOURNAL, **16**, 2, 211 (March, 1942).
6. Rudolfs, W., Ziemba, J., and Gehm, H. W., "Effect of Chlorine Dosage Upon the Percentage Reduction of *B. coli*." THIS JOURNAL, **6**, 6, 1094 (November, 1934).
7. Schmelkes, F. C., "Oxidation-Potential Concept of Chlorination." *Jour. Amer. Water Works Assoc.*, **25**, 695 (1933).
8. Moore, W. A., Megregian, S., and Ruchhoft, C. C., "Some Chemical Aspects of the Ammonia-Chlorine Treatment of Water." *Jour. Amer. Water Works Assoc.*, **35**, 10, 1329 (1943).
9. Griffin, A. E., and Chamberlain, N. S., "Exploring the Effect of Heavy Doses of Chlorine in Sewage." THIS JOURNAL, **17**, 4, 730 (July, 1945).
10. *Standards Methods for the Examination of Water and Sewage*, 8th Edition. American Public Health Association, New York, N. Y. (1936).

INVENTORY OF SANITATION FACILITIES

More than 900 copies of the recently-published *Inventory of Water and Sewage Facilities* in the United States have already been distributed to State health departments and other public and private organizations interested in environmental sanitation, according to Assistant Surgeon General Mark D. Hollis, Chief of Engineering Activities, U. S. Public Health Service.

The new publication, which is the first comprehensive listing of communities and their sanitary facilities made available in this country, lists all incorporated places of over 100 population and all unincorporated communities of over 500 population. Therefore, it also furnishes current information on basic needs in the sanitation field.

The Inventory was prepared by the staff of the Public Health Service Environmental Health Center (formerly Water and Sanitation Investigations Station) at Cincinnati, Ohio, in cooperation with Sanitary Engineering Divisions of the States. It includes details on sources of water, type of water treatment plant, methods of treating sewage (or lack of such treatment), and sewerage facilities for each community listed.

Copies of the Inventory may be obtained on request from the Officer in Charge, Environmental Health Center, Public Health Service, 1016 Broadway, Cincinnati 2, Ohio.

Industrial Wastes

COMPRESSED YEAST WASTES TREATMENT.*

IV. Trickling Filter Studies

By Willem Rudolfs and Eugene H. Trubnick

The trickling filter process has been applied with varying degrees of success to the treatment of several different types of industrial wastes. Milk wastes (1) have been treated by this method, with B.O.D. removals as high as 90 per cent by a high-rate recirculating filter treating 16 m.g.a.d. of waste containing 500 p.p.m. raw B.O.D. In pilot plant studies (2), it has been found that in the treatment of strawboard wastes containing 475 to 1110 p.p.m. B.O.D., removals of 58 to 77 per cent were effected with loadings of 720 to 2900 lb. B.O.D. per acre-ft. per day. Jensen (3), working with waste waters from a yeast plant, has used trickling filters as secondary treatment for a liquid effluent previously treated by anaerobic digestion and intermediate ponding. Material entering the filters had a B.O.D. of 330 p.p.m., and a 70 per cent B.O.D. removal was obtained. Probably on account of the relatively low loadings, 30 to 60 per cent of the ammonia nitrogen in the influent was nitrified, resulting in effluents containing 200 to 400 p.p.m. nitrate nitrogen. An additional 20 per cent of the ammonia was lost and could not be accounted for as nitrite or nitrate.

The authors, in a previous paper of this series (4), reported on investigations with a small-scale laboratory filter. In those investigations the rate of flow was kept constant at 1 m.g.a.d. Loadings of 250 to 550 lb. B.O.D. per acre-ft. per day, representing raw B.O.D. values of 250 to 400 p.p.m., resulted in 80 to 87 per cent B.O.D. removal and produced effluents containing 34 to 62 p.p.m. B.O.D. Slightly higher loadings of 600 to 734 p.p.m. resulted in 50 to 60 per cent removals, producing effluents containing 300 p.p.m. B.O.D. Ammonia removal decreased steadily with increasing loading, from 85 per cent removal at a 280-lb. loading to 32 per cent at a 602-lb. loading; nitrate content of the effluent was 37 to 83 p.p.m.

Description of Equipment

In order to study filter performance at higher loadings than could be achieved with the small scale laboratory filter, to obtain information regarding various methods of operation including shock loading and short duration of rest periods, to study various aspects of effluent recirculation as well as to compare large scale operation with laboratory experiments, investigations on the treatment of wastes from the manufacture of compressed yeast by trickling filters were conducted on a pilot plant scale.

The pilot plant consisted of two circular filters, each 15 ft. in diameter and 4 ft. deep, filled with crushed rock (passing through a 2½-in. screen and retained on 1-in.) underlaid with horseshoe tile. Measured flows were fed to the filters through rotating arms, either

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Sanitation, New Brunswick, N. J.

FIGURE 1.—Pilot trickling filters at Anheuser-Busch Yeast Plant, Old Bridge, N. J.

directly from a holding tank as raw spent nutrient and wash water or from an intermediate settling tank as digester effluent, or as mixtures of wash water and digester effluent. The filter effluent flowed by gravity to a sump from which it could be pumped either to recirculation or to a final settling tank for discharge to the sewer. Provisions were included for the introduction of measured flows of dilution water. Piping was arranged for maximum flexibility, so that by means of valves, flows could be directed to the two filters in series or in parallel; and, when in series, in either sequence. A view of the filters and recirculation equipment is shown in Figure 1.

Comparison of Flow Plans

A comparison was made of various flow plans within the application range of 300 to 2800 lb. raw B.O.D. per acre-ft. per day. The flow plans used were as follows:

(a) Series, no recirculation.

(b) Series, 1:1 recirculation; volume equivalent to raw flow returned from secondary effluent to primary influent.

(c) Series with secondary recirculation; volume equivalent to raw flow returned from secondary effluent to secondary influent.

(d) Series with split recirculation; volume equivalent to raw flow returned from secondary effluent to secondary influent, and equal flow returned from secondary effluent to primary influent.

(e) Series with multiple recirculation; volume equivalent to raw flow returned from secondary effluent to secondary influent, 50 per cent of flow from secondary effluent to primary influent, 50 per cent from primary effluent to primary influent.

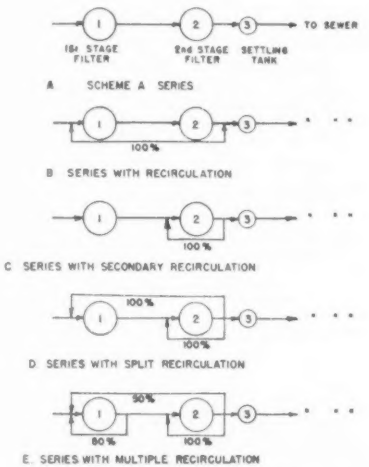

FIGURE 2.—Flow sheets, trickling filter studies.

These flows are diagrammatically illustrated in Figure 2.

The results obtained with relatively low loadings, using various methods of filtration and recirculation, when plotted on the basis of pounds B.O.D. applied per acre-foot per day (Figure 3), show an over-all average of approximately 50 per cent B.O.D. reduction, irrespective of the loading. However, it appears that with increasing complexity of filtration and recirculation the amount of work done by the filters decreased. For instance, if the results obtained by series operation with multiple recirculation (Scheme E) are compared with series operation and simple recirculation (Scheme B), the B.O.D. reductions at loadings of 1000 lb. per acre-ft. were, respectively, about 30 and 50 per cent. The results indicate further that the various forms of recirculation allowed no higher loadings or produced no better purification than simple two-stage filtration without recirculation. The results presented are not strictly comparable, because the possible effects of seasonal variations have been neglected.

Effect of Recirculation

The effect of recirculation, using raw wash waters at a higher rate of B.O.D. loadings, is indicated in Table I. The B.O.D. applied with recirculation includes the weight of the B.O.D. in the recirculated water. It appears from these figures that recirculation does not improve results. This is more clearly shown in Figure 4, where the pounds B.O.D. removed are plotted against the loadings. It may be argued that the inclusion of the B.O.D. of the recirculated water places this method at a disadvantage, because the so-called easily oxidizable material in the raw wastes would be removed by the filtra-

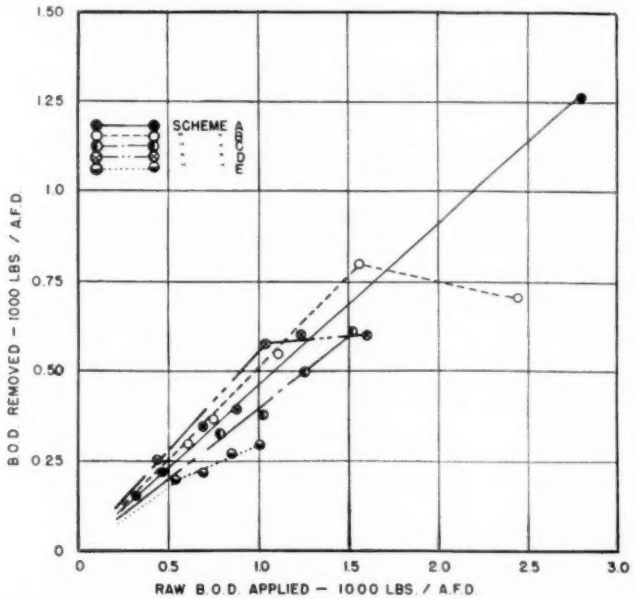

FIGURE 3.—Comparison of results obtained by various methods of filtration and recirculation.

TABLE I.—Effect of Recirculation on Treatment of Raw Wash Waters

No Recirculation			Recirculation 1:1		
B.O.D. Applied (lb./a.-f./d.)	B.O.D. Removed		B.O.D. Applied (lb./a.-f./d.)	B.O.D. Removed	
	Lb./A.-F./D.	Per Cent		Lb./A.-F./D.	Per Cent
2800	1270	45	1670	1000	58
4450	2900	65	3830	1800	47
7040	3560	51	6930	2270	33
8790	5440	62	9040	2540	28
Av. 5770	3290	57	5380	1930	36

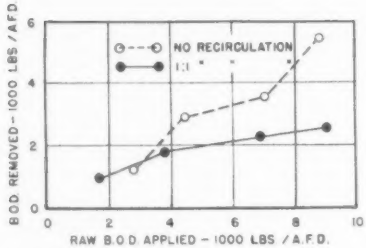

FIGURE 4.—Effect of recirculation on trickling filter treatment of raw wash water.

tion without recirculation and the less readily oxidizable material would be a part of the load on the filters when recirculation was practiced. Moreover, the results of B.O.D. removal without recirculation appeared to be more erratic than those with recirculation.

A similar comparison, using mixtures of anaerobically digested spent nutrients and wash waters, showing the raw as well as the total B.O.D. loadings in pounds per acre-foot, is given in Table II. With raw B.O.D. loadings of up to 8000 lb. per acre-ft. per day, the quantity of B.O.D. removed was the same whether the material was recirculated or not. At 8000 lb. B.O.D. of raw digester effluent applied the total loading including recirculation was 12,000 lb. per acre-foot. Beyond this loading the filters receiving recirculated water deteriorated more rapidly than the filters without recirculation, with the result that the

TABLE II.—Effect of Recirculation on Filtration of Digester Effluent

No Recirculation			Recirculation 1:1				
Raw B.O.D. Applied (lb./a.-f./d.)	B.O.D. Removal		Raw B.O.D. Applied (lb./a.-f./d.)	B.O.D. Removal		Total B.O.D. (lb./a.-f./d.)	Total Removal (%)
	Lb./A.-F./D.	Per Cent		Lb./A.-F./D.	Per Cent		
390	190	49	340	190	55	500	38
2,820	1,290	46	500	290	58	740	39
5,860	2,720	46	590	260	44	900	27
7,250	3,250	45	950	460	49	1,430	32
7,630	3,820	50	1,310	720	55	1,970	36
8,610	3,690	43	2,230	870	39	3,350	26
9,060	4,090	45	2,260	920	41	3,400	27
9,520	4,540	48	4,170	2,100	50	6,250	33
10,360	4,540	44	6,930	2,920	43	10,400	28
11,490	4,880	42	8,190	3,690	45	12,290	30
12,900	5,210	41	9,040	2,580	28	13,600	19
13,000	5,080	39	10,770	2,350	22	16,150	15
Av. 8,240	3,760	46	3,110	1,445	46	5,920	24

amount of work done (B.O.D. removed) became less, whereas the amount of work done by the filters without recirculation increased. The percentage removal based upon the total loading with recirculation was lower over the entire range of loadings as compared to the percentage B.O.D. reduction accomplished without recirculation. The recirculation ratios remained constant over the entire range, but the volume loadings varied with and without recirculation. Irrespective of recirculation it appears that the percentage B.O.D. reduction gradually decreases with increased loadings until the loading becomes so high that a sudden breakdown occurs. This tendency is illustrated in Figure 5, where the per-

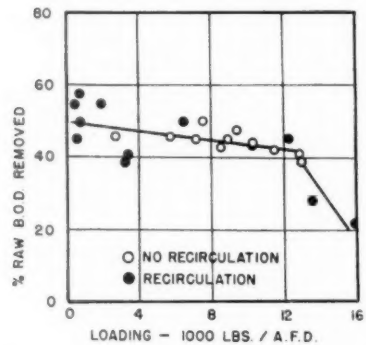

FIGURE 5.—Effect of total loading on percentage B.O.D. reduction.

centage of raw B.O.D. removed is plotted against total B.O.D. applied. The total loading allowable with the material treated appears to be approximately 12,000 lb. B.O.D. per acre-foot.

Effect of Rate of Flow and Surface Applications

Within the relatively low limits of surface application for high-rate filters of 0.8 to 6.8 m.g.a.d. no significant variations were observed in the percentage B.O.D. removal. It appears that the increase in load is more important than the rate of flow, as illustrated by the results in Table III.

TABLE III.—Effect of Rate of Flow on Percentage B.O.D. Removal

Rate of Flow (m.g.a.d.)	Per Cent Removal For Various Ranges of Raw B.O.D.		
	170–446 p.p.m.	546–994 p.p.m.	1070–1475 p.p.m.
0.76	56	—	—
3.28	46	56	62
3.92 to 4.52	—	44	48
5.16 to 5.80	—	38	37
6.28 to 6.32	—	46	—

Effect of B.O.D. Concentration

A series of studies conducted to determine the effect of raw B.O.D. concentration on the quality of the effluent and percentage B.O.D. reduction show that the latter did not materially differ with concentrations varying from 300 to 1425 p.p.m. whether or not recirculation was used. The B.O.D. remaining in the effluent increased steadily with increasing B.O.D. of the raw material. The relation between original concentration and B.O.D. in the effluent is shown in Figure 6 for results obtained with and without recirculation. At the lower initial B.O.D. concentrations the percentage removal is somewhat higher than at the high initial concentrations.

Effect of Pre-Digestion

The possibility that so-called easily decomposable material would be destroyed by anaerobic digestion, leaving only more resistant material to be oxidized in the filters, was studied by comparing the degree of purification attained with various mixtures of raw and digested spent nutrients and wash waters. In combining results obtained with and without recirculation the tendency seemed to be that digested material showed a somewhat higher percentage B.O.D. reduction, but when the results were separated and ana-

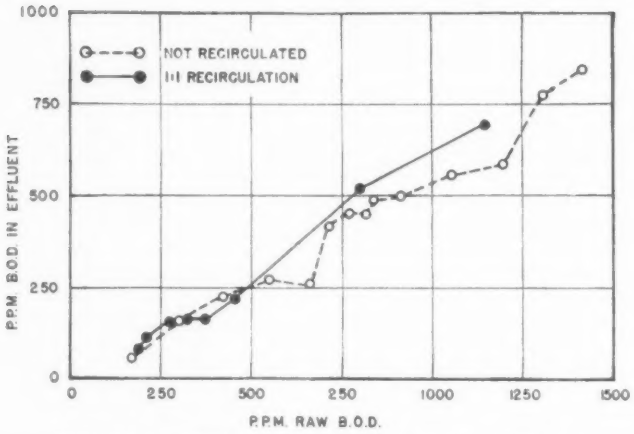

FIGURE 6.—Effect of concentration on quality of effluent.

lyzed it was found that the filter efficiency was not materially affected by pre-digestion. Some results obtained with various loadings illustrate the findings:

Material Treated	No Recirc.	With Recirc.	Av.
Raw Spent Nutrient; Raw Wash Water	53	39	43
Digested S. N.; Raw W. W.	43	47	44
Digested S. N.; Digested W. W.	49	48	48

It appeared that the total B.O.D. loadings applied were a more important factor than was pretreatment by digestion.

Effect of pH

The raw spent nutrients and raw wash water had pH values below 5.6, whereas in all cases where anaerobically digested spent nutrients and wash water were applied to the filters, the pH of the influent was 7.0 or higher. The pH values between 5.6 and 7.0 were attained by partial neutralization of the raw material with NaOH, Na_2CO_3, or waste alkali. By averaging all results obtained with B.O.D. loadings between 1000 and 5000 lb. per acre-ft. daily, it was found that, in general, the filter performance improved with increasing pH values in the influent. This is illustrated by the following average figures, in which the effect of loading, strength of waste, recirculation and pre-digestion are neglected:

pH of Influent	B.O.D. Removal (%)
5.05	34
5.55	42
6.0	47
6.6	48
7.0	51
7.35	41

The optimum B.O.D. removal occurred when the pH value of the influent was 7. Passage of the waste through the filter increased the pH, so that with pH values of over 7.0 in the influent, the effluent had pH values of 8.4 to 8.6. With the pH of the influent around the neutral point the effluents had pH values between 7.6 and 8.

With influent pH values of 6 and below, the surface of the rock rapidly became coated with a heavy reddish brown growth of wild yeast, resulting in clogging of the filters. Since the

optimum pH values for the growth of wild yeast appeared to be below 6, experiments were conducted with partial neutralization, using sodium hydroxide for the purpose. Neutralization of the waste to pH 6.5 before digestion or to pH 7 of the raw material resulted in the disappearance of the surface growth within two weeks. The question was raised whether the disappearance of the wild yeast could be accomplished with chemicals other than sodium hydroxide. Experiments with sodium carbonate and waste alkalies showed that whenever the pH values of the influent were raised sufficiently no wild yeast growth occurred; and that existing growth could be removed. It appears, therefore, that in addition to aiding the purification, partial neutralization was a valuable tool to prevent clogging of the filters.

Nitrogen Changes During Filtration

The spent nutrients and wash water contain appreciable quantities of organic and ammonia nitrogen. The percentage reduction of organic and ammonia nitrogen varied, but amounted on the average to about 35 and 25 per cent, respectively. Some results obtained are presented in Table IV to indicate the variations in initial nitrogen concentrations and the quantities found in the effluent. High-rate filtration is not conducive to nitrification. Only relatively small quantities of nitrates were found in the effluent.

TABLE IV.—Nitrogen Changes during Filtration

Organic—N (p.p.m.)		Ammonia—N (p.p.m.)		Nitrate—N in Effluent (p.p.m.)
Influent	Effluent	Influent	Effluent	
172	118	64	64	0
234	215	120	139	0
146	128	218	192	0–5
478	201	309	232	0–6
249	182	398	271	0–2.5
208	115	475	280	0

The reduction in organic nitrogen and probably most of the reduction in ammonia nitrogen are assumed to be caused by assimilation by the microorganisms.

Work Done by Individual Filters

The amount of work done by the individual filters in a two-stage filter system is not the same. Of the total amount of B.O.D. removed by the two filters, it appears that, in general, between 50 and 60 per cent of the work is done by the primary filter. Disregarding the strength of the raw material, an attempt was made to determine what effect, if any, variation in flow would have on the work done by the individual filters. It appears that when no recirculation was practiced more work was done by the primary filter than by the secondary filter when based on the original load (Table V), but with recirculation the amount of work done was about the same in both filters, except at very high flows when most of the work was done

TABLE V.—B.O.D. Removal by Primary and Secondary Filters at Various Flows

Flow (m.g.a.d.)	Total B.O.D. Removal (%)		B.O.D. Remaining (%)	
	Filter 1	Filter 2	Filter 1	Filter 2
No Recirculation				
1.2	62	38	32	29
6.5	70	30	37	26
8.8	53	47	26	31
11.3	48	52	20	27
13.8	63	37	30	23
Weighted av.	58	42	30	28
Recirculated				
2.0	47	53	24	36
3.2	49	51	20	26
3.5	48	52	14	18
4.0	49	51	17	22
5.0	52	48	9	16
20.0	21	79	6	23
Weighted av.	48.5	51.5	16.5	27.5

by the secondary filter. The total amount of work done (expressed in pounds B.O.D. removed) at these high flows was greater than at low flows, but the percentage removal, or efficiency, was less.

Comparison of the efficiency of the primary and secondary filters by determining the percentage of B.O.D. removed of that fed to the particular filter, indicates that without recirculation the percentage B.O.D. removal was about the same, but with recirculation the percentage removal in the secondary filter was greater.

Effect of Dilution with Cooling Water

In the production of yeast a considerable amount of cooling water is discharged. This cooling water has a temperature of about 80° F. and contains a considerable amount of dissolved oxygen. Results of experiments made with varying amounts of cooling water added to the raw and digested materials before application to the filters are shown in Table VI. The results seem to indicate that dilution of the material with cooling water aids the performance of the filters. The benefit derived from the cooling water would be greater during cold weather, because of the higher temperature of the mixtures.

TABLE VI.—Effect of Dilution with Cooling Water on Percentage B.O.D. Reduction

No Recirculation		Recirculation 1:1	
B.O.D. Raw (p.p.m.)	B.O.D. Reduction (%)	B.O.D. Raw (p.p.m.)	B.O.D. Reduction (%)
172	65	184	58
303	48	209	47
546	50	275	48
660	51	316	48
811	44	370	55
1055	47	452	52
1305	41	802	35
1425	40	1142	39

Discussion

At low loadings of 300 to 500 lb. B.O.D. per acre-ft. per day trickling filter performance by the pilot plant filters was lower than that obtained by laboratory results previously reported (4). With high loadings the shallow high-rate filters removed considerable amounts of organic and ammonia nitrogen, but little or no nitrification occurred.

With the exception of the lower and higher limits of loading the filter performance remained at a value of approximately 50 per cent B.O.D. removal. As a result, as loadings increased, the actual pounds of B.O.D. removed increased. In general, the efficiency of the filters remained fairly constant regardless of the rate of flow or B.O.D. concentration applied. The rather constant efficiency was maintained with loadings up to about 11,000 lb. of B.O.D. per acre-ft. per day, or about 44,000 lb. per acre for the 4-ft. deep filters used. Higher loadings caused a marked decrease in the efficiency of the filters.

The magnitude of the loading values applied to the filters was materially higher than ordinarily used in sewage treatment practice. It should be borne in mind that the materials treated consist predominantly of dissolved solids, much of which is organic in nature and readily available for biological assimilation. It appears that in the treatment of soluble wastes such as from the manufacture of compressed yeast, loadings can be applied far in excess of those practiced with domestic sewage, without resorting to recirculation.

Recirculation appears to be of interest only in respect to dilution of concentrated material. If the total B.O.D. removal with recirculation is plotted against the loading expressed in terms of total B.O.D. applied, including the load of the recirculated B.O.D., recirculation results appear to be lower than results obtained with-

out recirculation. If, on the other hand, B.O.D. removal is plotted against the loading represented by the raw material applied, the results are similar to those found without recirculation. For instance, a loading of 8,000 lb. raw B.O.D. per acre-foot per day with recirculation corresponds to a total loading of about 12,000 lb. per acre-ft. per day. At total loadings up to 12,000 lb. per acre-ft. daily the percentage of raw B.O.D. removal with recirculation is of the same order as the percentage removal without recirculation. It seems, therefore, that the filter performance as measured by percentage removal is determined by the total loading, while actual removal, expressed in pounds per acre-foot per day, appears to be determined by the raw B.O.D. applied. In other words, whereas the total loading determines filter performance, the raw B.O.D. loading determines the actual work done. The recirculated organic material is not acted upon and the recirculated liquid functions essentially as a diluent. This function is of importance when concentrated material is treated.

The quality of the effluent appears to be a function of the concentration of the material applied to the filters. Furthermore, some evidence was shown that the filter performance is improved with application of more dilute material, as shown by the tendency of greater percentage removals with lower B.O.D. values in the raw material applied. Hence, recirculation together with dilution with available cooling water would be beneficial. In addition, the cooling water used for dilution is beneficial in maintaining higher temperatures of the mixtures, allowing biological activities to proceed at a greater rate, particularly during cold weather. The cooling water also carries a considerable amount of dissolved oxygen, thereby enhancing the over-all benefit derived from the practice of mixing it with digester effluent and raw wash water.

The reduction of ammonia and organic nitrogen by passage through the filters without material nitrification leads to the assumption that a part of the nitrogen was resynthesized biologically in the growth of the organisms, whereas another part of the nitrogen was volatilized as ammonia. The volatilization was evident, especially during warm weather when activity was high in the filters, by the ammoniacal odors eminating from the filters. The odor eminating from the filters resembled the pungent ammoniacal odor in horse barns. The odors dispersed readily in the surrounding atmosphere and were not noticeable a few yards away from the filters.

The best performance of the filters occurred when the waste was about neutral. With pH values below 6 the filter stone became covered with wild yeast, resulting in clogging. The growth of these wild yeasts was readily controlled by partial neutralization of the raw material to not less than pH 6.5, using sodium hydroxide, sodium carbonate or waste alkali. Whether the covering of the active film on the stone by the wild yeast, ultimately resulting in clogging, was responsible for the reduction in performance of the filters, or whether the more acid condition of the substrate retarded normal biological activities, was not determined, but it is believed that the material with lower pH values reduced biological activities in the film and stimulated yeast growth, which resulted in clogging and further deterioration. The degree of neutralization required depends upon the relative amounts or raw wash water and digested material in the mixtures to be treated.

Summary and Conclusions

Experiments were conducted over a period of about 5 years on the treat-

ment of compressed yeast wastes in the form of raw wash water, raw spent nutrients, digested wash water, digested spent nutrients, and various combinations of these materials, using trickling filters 15 ft. in diameter and 4 ft. deep. Various methods of operation and recirculation were used. The summarized data presented indicate that:

1. The trickling filters effected approximately 50 per cent B.O.D. removal, irrespective of whether the material applied was in the form of raw or pre-digested material or mixtures of raw and pre-digested material.

2. Loadings as high as 11,000 to 12,000 lb. B.O.D. per acre-ft. per day were possible without material retardation of purification.

3. The quality of the effluent depended upon the raw B.O.D. concentration. Recirculation appeared to be of value only as a means of diluting the concentrated materials.

4. Addition of cooling water as a diluent aided purification. In addition it helped in maintaining a higher temperature and supplied dissolved oxygen.

5. Within the limits of 0.19 to 1.73 m.g. per acre-ft. a day, the rate of flow or surface application did not significantly affect the filter performance.

6. The percentage B.O.D. removal was about equal in the primary and secondary filters, when recirculation was used, but was somewhat higher in the primary filter without recirculation.

7. Maximum purification occurred at an optimum pH of 7 of the material applied to the filters. Application of waste with pH values below 6 resulted in wild yeast growth and clogging. Wild yeast growth could be readily controlled by partial neutralization of the waste with an alkali.

8. Considerable reduction in ammonia and organic nitrogen occurred without appreciable nitrification.

References

1. Eldridge, E. F., "High-Rate Recirculating Filter for Milk Wastes." *Sewage Works Eng.*, **11**, 599 (1940).
2. Technical Bulletin No. 7. "Strawboard Waste Research Report," p. 59. Nat. Council for Stream Improvement, New York (Jan., 1947).
3. Jensen, K. E., "Purification of Waste Water from Yeast Factories." *Trans. Chem. Engr. Cong. of the World Power Conf.*, London, Paper F2 III: p. 253 (1937).
4. Rudolfs, W., and Trubnick, E. H., "Treatment of Effluents from the Manufacture of Compressed Yeast. II. Biological Treatment in Laboratory Pilot Units." THIS JOURNAL, **21**, 1, 100 (January, 1949).

JOURNAL BACK NUMBERS

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TREATMENT OF WASTES IN A METALWORKING PLANT *

By Harry D. Unwin

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The increasing public resentment toward stream pollution by industrial wastes and the rising clamor for action against offending concerns is quite understandable. It is reminiscent of the hue and cry set forth against the undesirable effects of dumping domestic sewage into streams and on farm land many years ago. Due to this increasing agitation, costly research and extensive investigations have resulted in the present status of sewage treatment plants.

Industries have expanded and increased in number and size in much the same manner as villages became towns and towns grew into cities. Consequently, the pollution load caused by industrial wastes has exceeded the purification ability of natural resources as well as the capacities of many municipal sewage plants. To alleviate this condition, two solutions are at once suggested: (1) the processing of the existing wastes by each manufacturing plant, and (2) the incorporation of adequate facilities in the original design of new plants. The second method of solving the problem is receiving just consideration by all forward-looking managements and is exemplified by the industrial waste treatment system designed and constructed in connection with the ball-bearing plant completed last year at Sandusky, Ohio for the New Departure Division, General Motors Corporation.

The trend is definitely toward locating new plants in small communities and on the outskirts of large cities beyond the range of municipal sewage systems. This often necessitates the construction of independent sewage treatment plants into which it is frequently unwise to incorporate facilities for handling the industrial wastes. Consequently, the trade wastes must be discharged to the storm sewers which, in many cases, discharge to some small stream where there is insufficient flow to provide the necessary dilution.

As a result of the increasing amount of trade waste discharge, it is apparent that suitable collection, treatment and disposal facilities must be given equal consideration with the planning of manufacturing operations during the layout and design of new plants.

Industrial wastes vary considerably in different industries and to a lesser extent within plants of the same industry, depending upon the products manufactured and the processes employed. As the New Departure plant is the first fully integrated ball-bearing plant ever constructed, it was natural that improvements in layout and manufacturing technique should be introduced that are economically unattainable in older plants which have gradually expanded to their present size.

Approximately 563,000 sq. ft. of floor space under one roof comprises the manufacturing area of this plant. Industrial wastes originate in various departments occupying the greater portion of this area including the ball shop, press room, machining department, heat-treat, grinding, pickling, chrome plating, laundry and dry cleaning room, forge shop, etc.

* Presented at Twenty-second Annual Meeting, Ohio Sewage and Industrial Waste Conference, Dayton, Ohio, June 24, 1948.

The alkali cleaning machines, pickling of steel, chrome plating and renewal of coolant make-up tanks are the primary sources of objectionable trade wastes, although the laundry, wet dust collectors, and miscellaneous operations involving the use of insoluble oils such as quench oil, mineral seal oil, hydraulic oil, cutting oils and emulsions contribute to the total waste output of the plant.

Analysis of Problem

In investigating any waste handling problem, there are three methods of approach:

1. Consider each waste independently and determine the economic possibilities of reclamation so as to eliminate the necessity of disposal. In many metal-working plants, the volumes of individual wastes usually are too small to warrant extensive recovery systems, except in the case of soluble oils used as coolants. Due to the large expenditure involved in equipment and distribution systems for soluble oil recovery and re-use, sufficient savings may not be realized to justify such an investment and amortize it in a reasonable length of time. This investment is compared with that required to handle and treat the soluble oil for disposal, bearing in mind that there probably will be no salvage value to the waste thus obtained. Obviously, the answer bears no relationship to the original cost of the soluble oil, but is entirely a question of the economical handling of the material once it has served its purpose and is discharged from the machines.

2. Consider each waste product independently of the others and provide means of treatment or disposal to eliminate it completely before proceeding to analyze any other of the existing trade wastes. This method may be very uneconomical. Where several trade wastes are present, a careful study of the characteristics and volume may indicate that one or more may be utilized to neutralize or treat another, thus reducing or eliminating the purchase of chemicals.

3. Completely survey all of the trade wastes in the manufacturing plant, carefully analyze the quantity and characteristics of each, and then develop an over-all plan for the treatment or disposal of the various wastes, taking into consideration economy of treatment and flexibility of the collection systems as well as that of the treatment process. This method of approach was followed in the design of the New Departure waste treatment facilities because it permitted utilization of the waste pickle liquor to "crack" the emulsified soluble oil present in the alkali wastes.

Mills Creek has practically no flow at certain seasons of the year at the point where the outfall is located. It winds through farm land and passes through a golf course before entering the Sandusky storm sewer system that ultimately empties into Lake Erie. Toxic wastes, if allowed to enter the stream, would not be sufficiently diluted thereby to become harmless to grazing cattle. Also, the discharge of soluble oils which had been partially reduced by the acid wastes would be completely broken by further dilution, thus permitting the collection of oil on the surface of the stream in quiescent areas during its winding flow through the golf course. Such oil is not only unsightly but it can also become a real hazard, particularly if flammable cleaning agents such as kerosene or other solvents are present.

In view of these conditions, the following maximum concentrations of objectionable substances in the plant storm water discharge were established by the Ohio Department of Health:

Chromium	2.0 p.p.m.
Emulsified Oils	30.0 p.p.m.
Suspended Solids	20.0 p.p.m.
pH range	7.0 to 10.0

The Ohio statutes specifically require that any new industry, or one making changes and additions to existing establishments, which has industrial wastes, must submit plans of treatment and disposal facilities to the state department of health for approval prior to construction. This section of the General Code is interpreted to mean that such treatment facilities be installed simultaneously with the construction of a new industrial plant and that they constitute an integral part of industrial process development.

Characteristics of Wastes

The wastes were classified according to their composition and origin as follows:

1. The weak alkali group of wastes includes all of the rinse waters from the washing machines and plating department, lime dip tank discharge, oily wastes from the steam cleaning room, insoluble waste oil, laundry discharges and the contents of the alkali cleaner tanks of the washing machines, when found too contaminated for satisfactory operation.

2. The spent pickle liquor, which has developed too high an iron sulfate concentration for efficient scale removal, is grouped separately in order to study its relationship to the alkali and soluble oil wastes.

3. The sulfuric acid-bearing rinse waters from the pickling machine, and the chromic acid-bearing rinse waters from the plating and Parkerizing systems were grouped together as weak acid wastes for further analysis.

4. Discharges from the central coolant system in emergencies or as required for maintenance purposes.

The amount of spent pickle liquor discharged weekly will assist the weak acid waste to neutralize the weekly quantity of soluble oil, lime and alkali cleaning agents which comprise the weak alkali waste, as well as to crack a reasonable amount of soluble oil from the make-up tanks if this should be required. It therefore appeared economical to segregate the pickle acid as a raw material for treating purposes, and separation of the concentrated waste coolant that might be discharged would prevent large quantities of this waste from upsetting the normal character of the weak alkali group of wastes. Since the weak acid waste will also contain chromic acid, this must also be segregated to reduce the quantity to be treated for chromium reduction.

The total estimated flow of all wastes, for 150 per cent peak load, contains the following contaminating elements:

Type of Waste	Parts per Million
Alkali as Na_2O	1500
Sulfuric Acid	3900
Ferrous Sulfate	2200
Chromium	3
Soluble Oil	2300
Insoluble Oil	650

If the plating department should be operating without benefit of diluting rinse waters from the pickling machine and alkali washing machines, there would be a possible chromic acid concentration of 20.9 p.p.m. in the rinse water. By the same reasoning, the rinse water from the pickling system has a concentration of 43.7 p.p.m. Furthermore, if the soluble oil tanks on the various machines, isolated from the central system, are dumped during a shut-down period, the concentration might be 20,000 to 30,000 p.p.m. or higher.

Waste Collection Systems

Wide variations in flow rates and degree of contamination of individual industrial wastes are not conducive to an economical control or treatment system. Impounding the wastes in large reservoirs prior to disposal or introduction into the treatment system tends to produce more uniform composition within each reservoir, as well as to permit controlled rates of flow therefrom

through the treatment process. Two major waste collecting systems are provided; one for acid wastes and one for alkali wastes.

The alkali collecting system in the factory consists of an overhead system of piping in the truss space into which all alkali and oil-bearing wastes are pumped from sumps located at the metal washing machines, lime rinse tank of the pickling machine, steam cleaning room, alkali waste sump in the plating department and at other production equipment where similar wastes originate. Both rinse waters and concentrated alkali wastes pass through this system to the receiving reservoirs. When the discharge of the coolant make-up tanks becomes necessary, it will be scheduled at a time when little or no alkali rinse waters are flowing so that this concentrated waste may be impounded separately.

The acid collecting system receives the gravity discharge of spent pickle liquor and acid rinse waters from the sulfuric acid pickling of strip coils and from the chromium plating operation, respectively, which are considered permanently located departments. The pickling liquor is scheduled for dumping at a time when the sulfuric and chromic acid rinse waters are not flowing so that it may be impounded separately and held in reserve as a useful and low-cost treating agent.

With this arrangement of collecting the various wastes, a minimum of piping is required, maximum flexibility is provided, and at the same time the four major types of wastes—weak alkali, weak acid, pickling liquor and spent coolant—are properly segregated and made available for treatment and neutralization in any proportion desirable and necessary to dispose of the quantities involved.

Methods of Disposal Considered

Five methods of disposal were analyzed in connection with the design of the New Departure treatment plant:

1. Disposal by dilution.
2. Disposal by discharge into the sewage treatment system.
3. Disposal by settling and aeration.
4. Disposal by evaporation to dryness.
5. Disposal by chemical treatment.

The chemical treatment method affords a high degree of flexibility, since flow rates of raw wastes and treating agents can be controlled. It permits wide ranges of concentrations to be handled and is adaptable to the treatment of additional trade wastes with little or no change to the mechanical equipment. The chemical treatment plant can be operated continuously or on a batch basis, labor and power costs are at a minimum and the system can be made automatic if desired. For these reasons, this method was selected for the problem at hand.

The design of the treatment system is based upon handling 150 per cent of the estimated peak flow of trade wastes over a 24-hour period; that is, 125,000 gal. of weak alkali waste and 85,000 gal. of weak acid waste. In addition, provision is made to impound 8,000 gal. of spent pickling liquor and several thousand gallons of waste coolant.

In order to reduce the operating labor cost to a minimum, the rate of treatment and neutralization has been established on the basis of handling the ultimate 24-hour peak load in an 8-hour operating period. Therefore, the system as originally laid out has a maximum design capacity of 440 g.p.m. Since the ultimate design load of 150 per cent of the present estimated peak requirements will not be reached for some time, one-half of the final clarification equipment has been omitted. The system as installed will handle 75 per cent of the estimated peak load in an 8-hour operating period, or 130 g.p.m. of alkaline waste and 90 g.p.m. of acid waste, equivalent to 220 g.p.m. The economy of this is seen from the fact that the peak demand can actually

increase to 225 per cent before additional clarification equipment need be installed, merely by increasing the operating hours of the treatment plant to 24 hours if necessary.

The Treatment Process

The treatment process (Figure 1) is accomplished in four stages: (1) primary clarification for partial separation and removal of soluble and insoluble oils, (2) chromate reduction to reduce the chromium in the weak acid waste, (3) final clarification and neutralization, and (4) sludge dewatering and disposal. The receiving reservoirs permit the treatment of wastes therefrom to be a continuous process during the 8-hour daily operating period of the treatment plant. This arrangement has another advantage: when wastes are produced at a much slower rate than normal, they can be impounded in the reservoirs until sufficient have been accumulated to allow a full 8-hour operation of the treatment plant.

The caustic wastes from the weak alkali reservoir are pumped through a controlled level weir box to the 20-ft. diameter primary clarifier. To effect acidification and promote oil separation, a portion of the waste pickle liquor is pumped to the weir box, where mixing occurs with the alkaline waste. In the primary clarifier, the pH is maintained at about 5.0 for maximum oil separation. The separated oil and some precipitated iron hydroxide separates as a floating scum, which is removed by a hydraulic skimmer, and is carried by gravity to an underground tank. The partially clarified soluble oil-bearing alkali waste discharges by gravity to the final clarifier, where treatment is completed and neutralization effected.

When chromium is present in the rinse waters, a preliminary step is required to reduce the chromates from hexavalent to the trivalent form. The weak acid waste containing both sulfuric acid and chromic acid is pumped from the receiving reservoir through a

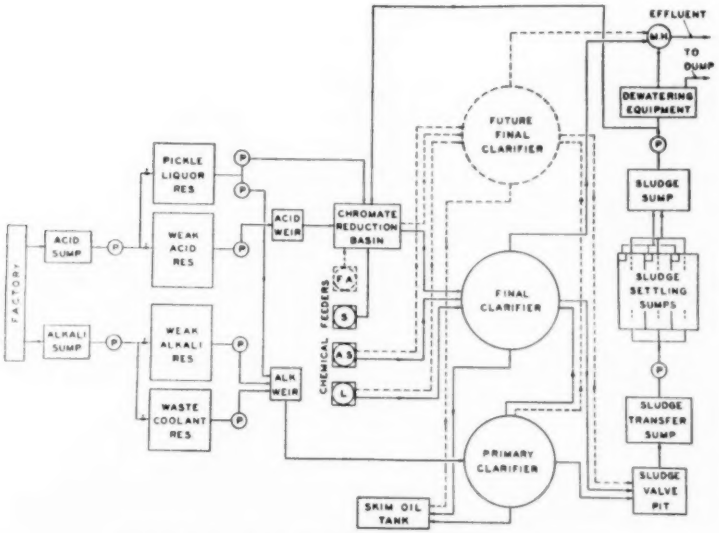

FIGURE 1.—Flow diagram of waste treatment process.

controlled level weir box to the rapid mix or chromate reduction chamber. Any excess spent pickle liquor is also pumped to this basin for disposal. At the same time, the ferrous sulfate content effects partial reduction of the chromium. More complete reduction of the chromates to trivalent chromium, prior to precipitation, is obtained by feeding a controlled amount of one of the stronger reducing agents such as sodium bisulfite or sodium hydrosulfite.

From the reduction basin the treated weak acid waste flows by gravity to the 30-ft. final clarifier where lime is added directly to the reaction chamber to effect neutralization and raise the pH to approximately 9.0 for better precipitation of the iron and chromic hydroxides. Activated silica is also added at the reaction chamber to improve coagulation and precipitation of the hydroxides.

The efficiency of final clarification is primarily a function of the rate of separation of the floc. Ferric sulfate, when used as a coagulant, tends to produce more rapid separation than ferrous sulfate, but the latter is available in the spent pickle liquor. The effect of the activated silica is to broaden the effective pH range of coagulation and to improve the coagulation, particularly during winter operation when the wastes are at a lower temperature, and it has the special advantage of increasing the compaction of the sludge formed.

Figure 2 illustrates the complete industrial waste treatment plant.

Clarification

The designs of the two clarifiers are somewhat different since the function of the primary unit is oil removal while that of the final clarifier is precipitation and separation of solids.

The primary clarifier has a baffled inlet tube at the center which receives the influent. This tube distributes and directs the flow downward and outward from the center where it rises and flows to the peripheral effluent weir. The denser material settles to the bottom and is progressively moved toward the center by the sludge scraping mechanism.

The final clarifier, or "Cyclator" (Figure 3), is constructed in a similar

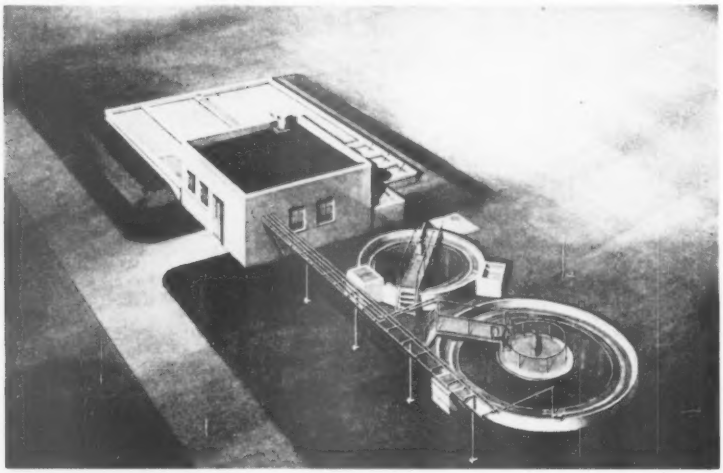

FIGURE 2.—Over-all view of New Departure industrial waste treatment plant.

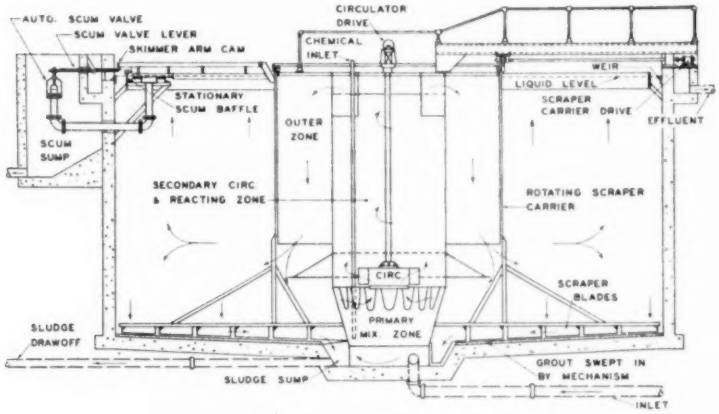

FIGURE 3.—Typical section of "Cyclator."

manner to the primary unit. The important difference is in the central inlet chamber where the primary clarifier effluent and the discharge from the chromate reduction basin are blended with the lime for neutralization and with activated silica for improved coagulation.

The settled sludge in the centrally located sumps of both clarifiers is periodically discharged through a solenoid controlled diaphragm valve on each clarifier sludge line. These sludge valves are located in a common pit (Figure 4) and are actuated by individual timers for intermittent opening. They are set for the proper frequency and duration of slurry discharge depending upon the rate of sludge formation in each individual clarifier. The combined underflow from the clarifiers flows by gravity to a transfer sump under the basement floor of the pump house, from which it is pumped to three settling basins (Figure 5), each having a capacity of approximately 15,000 gallons. A minimum retention period of 3 days is allowed for gravity separation of the solid particles of sludge when the

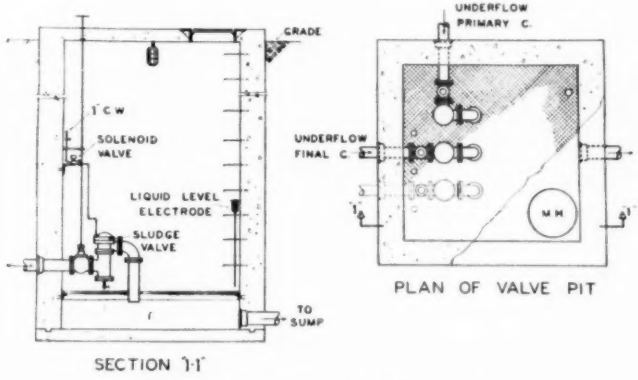

FIGURE 4.—Details of sludge valve pit.

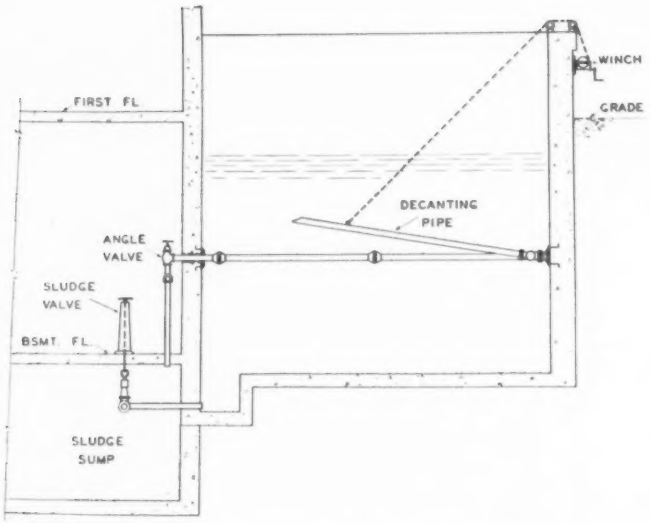

FIGURE 5.—Details of sludge settling basin.

treatment plant is on an 8 hour per day operating cycle.

After settling, as long as operations permit, the clear supernatant liquor is allowed to flow by gravity through an adjustable decanting pipe to the sludge sump from which it is pumped for disposal via the chromate reduction basin overflow to the final clarifier. When the supernatant liquor has been drawn down to the visible sludge line in the settling basins, the basins are refilled with newly-discharged slurry. This sequence of operations is continued until the solids have been concentrated three to four times, after which the thickened slurry is pumped to a lagoon for drying and disposal.

Operating Data

Economic flexibility in the layout of any waste treatment plant must provide means for adapting the facilities to reasonably severe changes in the composition of the wastes. The first few months of operation clearly substantiated the value of such practice. Chromium concentrations varied from 8.0 p.p.m. to 189 p.p.m, while the total oil content of the alkali waste ranged from 1000 p.p.m. to more than 100,000 p.p.m. The final effluent obtained analyzed below the concentrations established by the state authorities.

Minor piping changes were made to permit the use of the bisulfite feeder for feeding ferrous sulfate to the primary clarifier for breaking the soluble oil emulsions, and to the chromate reduction, or rapid mix basin, for chromium reduction. The reactions which occurred are, in general: (1) partial reduction of the chromium in the acid waste and formation of ferric sulfate, (2) high dosage to the primary clarifier released the soluble oil which was skimmed off, (3) the primary clarifier effluent contained excess ferrous sulfate and ferrous hydroxide, and (4) combining of the reduction basin discharge and primary clarifier effluent in the final clarifier resulted in reduction of the chromium below the required limit when sufficient lime was added for precipitation of the metallic hydroxides and neutralization.

Recent reports of plant operation indicate that the character of the wastes are "normal"; that is, wide variations in analysis of the acid and alkali wastes are less frequent and more uniform day-to-day concentrations of chromium and oil are being attained. Average operations show the following analyses:

Weak Alkali Waste:			
Alkalinity	150 – 400		p.p.m.
Total Oil	6,000 –16,000		p.p.m.
Weak Acid Waste:			
pH	2.1– 6.8		
Mineral Acidity	150 – 1,000		p.p.m.
Chromium (CrO_3)	1 – 19		p.p.m.
Final Effluent:			
pH	9.2– 10.6		
Chromium	tr. – 0.2		p.p.m.
Total Oil	2 – 20		p.p.m.

Conclusions

The development of a satisfactory industrial waste control system may be summarized as follows:

(1) Each industry and each plant within an industry is an individual unit, so that the waste control problems must be given special consideration in each case.

(2) Every possible method of control should be carefully investigated including dilution or treatment at the source, reclamation, segregation of wastes, and the many possible means of disposal.

(3) No one waste should be considered independently. The effect of other wastes and the probability of utilizing them to control or treat each other must be given serious analysis.

(4) The local conditions of sewers, streams and other waterways must be ascertained in order to determine the extent of treatment or dilution required.

(5) Flexibility of waste collecting systems and methods of control must always be borne in mind as changing production methods and utilization of different process liquids may easily make obsolete the entire waste control system.

(6) Perhaps of most importance to the control of industrial wastes is the subject of good housekeeping. Without proper supervision to guard against the discharge of oils and other wastes into sewers and places where they are not intended, the purpose of the entire waste treatment system will be defeated. As long as there is manual handling of process fluids to and from machines, constant vigilance must be exercised in the interest of good housekeeping.

DISCUSSION

By George A. McBride

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Few industrial waste treatment plants have handled successfully so severe and variable a waste problem as the plant which has been described by Mr. Unwin. From the start of the plant, and through a wide variety of conditions, the waste treatment process has consistently produced an effluent satisfactory to the need.

Features of certain equipment used in the plant may be of interest, especially the two types of treatment tanks. The clarifier is of the more or less standard type having provisions for removing any settleable solids from the bottom and for skimming from the top any material which is lighter than the main body of liquid being handled. This clarifier does its assigned duty by collecting effectively the free oil, both that which comes to the waste reservoirs in a free state and that which is broken out of emulsion form by the low pH environment pro-

vided by the pickle acid treatment. The amount of free oil passed to the second stage is negligible. The amount of coagulant necessary in the second stage is thereby reduced to that necessary to coagulate and absorb the emulsified oils which remain suspended.

But this first clarifier could not do the job for which the second treating tank, or "Cyclator," was designed, although the Cyclator could perform very well in the place of the clarifier, and offer some added advantages.

The reason that the clarifier could not do the job of the Cyclator is evident when it is recalled that as a settling unit, it is not called upon to prepare precipitates for effective and rapid removal by sedimentation. Before it could be expected to produce an effluent comparable to the Cyclator, additional equipment would have to be provided to mix the lime with the flows from the chromate reduction basin and from the clarifier to bring about the proper pH conditions for coagulation; then additional slow mixing equipment or coagulators with 20 to 30 min. contact time would be needed to build up the ferrous hydroxide floc to a settleable condition and to provide the intimate contact necessary for gathering all of the emulsified oil into the floc. Finally, without increase in velocity sufficient to destroy the floc so laboriously prepared, the coagulated flow would have to be transferred to the clarifier basin which, in turn, should not be doubled or tripled in size to handle this "gathered" rather than an "integrated" floc form. The term "integrated" as used here to describe the floc formed in the Cyclator is intended to convey the picture of a heavier, more rapidly separated floc formed when precipitation is allowed to take place only in the presence of previously formed precipitates.

This explains why the Cyclator could be used in place of the clarifier, but not vice-versa. In addition, the Cyclator might, if used in the first stage, be pressed into service in parallel with the second stage unit were it ever necessary or advisable to handle flows far above design flows pending expansion of the plant.

Dry feeders of the continuous ribbon, manually adjusted feed control type are in use on the hydrated lime feed and for any ferrous sulfate that may have to be fed over that contained in the pickle acid. Worthy of special mention is the batch type of activated silica feeder used here. It should be pointed out that were the flows greater, a continuous feeder could have been used; there is one of these in operation at Monroe, Mich., on a white water application of the Cyclator.

There is considerable evidence that the activated silica reduces the amount of coagulant necessary for gathering all the oil and reducing the bulk of the precipitates formed. It may also be that the character of the sludge from a dewatering standpoint is favorably affected by the silica.

With reference to the precipitation of ferrous hydroxide, there have been some questions raised as to why either alum or the ferric form of iron was not used, since in water treatment these latter two are generally favored as better coagulants. One obvious answer is that ferrous sulfate is present in the pickling acid as one of the "wastes" which could not be discharged into the stream untreated. Its acid character could be used to reduce the pH to provide a more favorable environment for emulsion breaking; it could be used as a reducing agent for the chromium and as a coagulant and absorbent for the oil; further, its ability to maintain a reducing environment could be counted on to help preserve the equipment from rust and thus reduce maintenance. Having recognized its usefulness and decided to match it off against the alkaline and acid waste problems, it seemed wise to augment

any deficiency of ferrous sulfate in the pickle acid with purchased ferrous sulfate if only to simplify the work of the operator.

The wisdom of Mr. Unwin's decision in this respect has been proven more than once by the flexibility of the plant over a wide range of concentrations under the part-time attention of a single man. There is evidence, too, that the exclusive use of the ferrous coagulant has yielded several blessings that were not fully anticipated. For one, it was expected that stronger reducing agents than ferrous sulfate might have to be used when the concentrations of chromium in the raw waste were low; with the mass action of the generous quantities of ferrous iron present, need for a stronger reducing agent has not yet been encountered. For another, unusually favorable action of the sludge in the lagoon has been observed, quite possibly due to the oxidation of the ferrous to ferric hydroxide in the lagoon. Such benefits would not be anticipated when using either ferric iron or alum precipitation. Finally, over quite a liberal range of pH the amount of ferrous iron left in solution in the treated effluent is quite small and, even after oxidation, represents usually only 5 to 10 p.p.m. of turbidity and only 2 to 5 p.p.m. of iron.

PROFITABLE WASTE TREATMENT

Construction has been completed and preliminary operations have started at the new $500,000 Maneely Chemical Company plant at Wheatland, Pennsylvania. Designed originally to solve at a profit the pickle liquor disposal problem of the parent companies, manufacturers of tubular metal products, the process is attracting wide attention throughout the steel industry and among industrial waste disposal engineers.

The process at Maneely utilizes two waste materials—spent pickle liquor and zinc wastes resulting from the galvanizing process—from the operations of the parent companies to make three salable products: ferric hydrate, zinc sulfate, and zinc chloride. Liquid chlorine is the only other raw material necessary in this original process.

The spent pickle liquor contains ferrous sulfate up to 22 per cent and free sulfuric acid up to 1 per cent. The zinc wastes are salskimmings having a total zinc content of about 50 per cent. They include metallic zinc, zinc oxide, zinc chloride, zinc oxy-chloride, ammonium chloride, iron and waste matter, and zinc ash having a zinc content of approximately 75 per cent and composed chiefly of metallic zinc and zinc oxide with small amounts of chlorides and iron.

The reactions involved are the dissolution of the zinc to take up the acid ions and the precipitation of the iron as ferric hydrate. Because zinc oxide dissolves in the pH range below 5, the iron hydrate precipitates in the range above 2, these materials are well suited to the reaction. If the ferrous ion is oxidized to ferric between pH 2 and 5, the iron sulfate will hydrolyze and precipitate as ferric hydrate, as the zinc takes up the acid ions freed in this hydrolysis. The speed of the reaction is influenced by heat, because it tends to cause rapid coagulation of the ferric hydrate gel and rapid solution of the zinc. The problem of resistance to chemical corrosion in the wet process was solved by using all monel piping and valves, together with glass-lined monel reactors.

PILOT PLANT TREATMENT OF DEINKING WASTE

By Philip F. Morgan

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The development of methods for treating deinking waste to prevent excessive pollution in the receiving stream has been a major project of the National Council for Stream Improvement for the past three years. The early work at the Mellon Institute of Industrial Research (1) had indicated that the B.O.D. and solids removal obtained by simple sedimentation or chemical coagulation and sedimentation would not be adequate in many cases. Later work carried on at Kalamazoo College (2) had indicated that biological treatment of deinking waste would be feasible. Pilot plant work was necessary to confirm the laboratory studies and to obtain design data. The pilot plant was also needed so development work could be carried forward on possible methods of utilizing or disposing of the treatment process by-products, the primary and secondary sludges.

The pilot plant as originally built (Figure 1) consisted of a primary settling tank, an aeration tank, a final settling tank, an air-lift pump for returning the secondary sludge, a final effluent measuring weir with recording meter, an indicating air flow meter, and the necessary valves and piping for operating the plant and for withdrawing and measuring the primary sludge and excess secondary sludge. A small trickling filter was later built and placed in operation to determine the practicability of this method of treatment, as an alternate to the aeration process. A small lagoon was placed in operation to study the practicability of lagooning the primary sludge.

The plant was in continuous operation from July 17 until November 25, 1947, when freezing weather interferred with further work. Throughout this period of operation, flow and process control data were obtained daily. Treatment efficiencies were determined by analysis of raw waste, settled waste and final effluent samples twice a week, each sample being a 9-hr. composite. This sampling schedule was considered adequate since the quantity of flow to the pilot plant was held constant for each period of operation and there was little variation in the quality of the waste because the deinking operation is continuous.

All analyses with the exception of the suspended solids determination were made in accordance with "Standard Methods" (3). Standard dilution water seeded with ½ per cent fresh settled sanitary sewage was used for B.O.D. dilutions, and dissolved oxygen was determined by the Winkler method using the sodium azide modification. The pH was determined with a Beckman Model G pH meter and turbidity with a Jackson turbidimeter. The suspended solids content of the mixed liquor was determined by the vacuum filtration method using Whatman No. 2 paper as the filtering media. The suspended solids content of the raw waste, primary effluent, and final effluents was determined by difference between the dissolved solids and the total solids of the sample, as it was found that this waste could not be successfully filtered because of the large amount of fine clay in suspension. The dissolved solids content of the sample was determined by evaporating

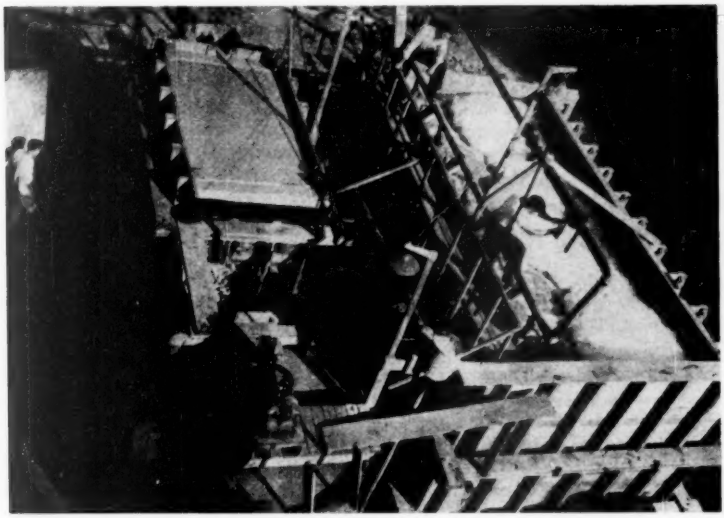

FIGURE 1.—The pilot plant.

the clarified liquor to dryness after centrifuging the sample for 5 min. at 4500 r.p.m.

Raw Waste

The raw waste B.O.D. during the period the pilot plant was in operation averaged 620 p.p.m., the pH averaged 9.36, the suspended solids 2670 p.p.m. and the suspended volatile 31.2 per cent of the suspended. This is typical of the waste from other deinking mills, so the results are indicative of what can be expected elsewhere.

Primary Treatment

The primary tank was 5 ft. 6 in. by 10 ft. in plan with a hopper bottom having 60° side slope and a total water depth of 9 ft. 6 in., thus providing a total volume of 2590 gal. or a net volume of 2140 gal. with allowance for sludge storage. The flow was distributed across the inlet end of the tank with a 3 ft. deep baffle in an attempt to divert the warm influent into the lower portions of the tank and thereby reduce short circuiting across the top. An outlet scum baffle was installed, but there was never any scum in evidence so that the need for such a baffle is not indicated in future designs.

Primary sludge was removed once or twice daily by gravity to a measuring barrel with little difficulty except that it was necessary to work the sludge down the sides of the 60° hoppers with a squeegee to start it flowing. No difficulty with sludge removal is anticipated in a conventional sedimentation tank equipped with a collector mechanism.

All data obtained on the characteristics of the raw and settled waste and the operation of the primary tank for the 23-day period from October 13 to November 4 are summarized in Table I. Space limitations make it impossible to present similar data for other periods of flow; however, the complete data are available in the National Council report on this project (4).

As a control on the sedimentation efficiency of the primary tank, a portion of each sample of raw waste was settled in the laboratory for 1 hr. in

TABLE I.—Primary Treatment Summary Data; Period E—October 13 to November 4, Inclusive

Average Flow (g.p.d.)	53,300
Primary Settling Period (hr.)	0.96
Raw Waste	
Temperature (°C.)	29.1
pH	9.5
Suspended Solids (p.p.m.)	2,441
Volatile Suspended (%)	26
B.O.D. (p.p.m.)	530
Imhoff Settled Waste	
Suspended Solids (p.p.m.)	1,326
Removal (%)	45.7
B.O.D. (p.p.m.)	399
Removal (%)	24.7
Primary Effluent	
pH	9.4
Suspended Solids (p.p.m.)	1,602
Volatile (%)	25
Removal (%)	34.4
B.O.D. (p.p.m.)	414
Removal (%)	21.9
Primary Sludge	
Volume (g.p.d.)	640
Total Solids (%)	9.4
Volatile (%)	36

an Imhoff cone and analyzed for total solids, suspended solids, and B.O.D. The results indicate that the B.O.D. removals in the primary tank were very nearly equal to those in the controlled settling test, but that the suspended solids removals in the primary tank were only 34 per cent as compared to 46 per cent in the Imhoff cone. Comparable data from other periods of operation indicate that the additional material settling out in the laboratory settling tests must be clays and carbonates having a negligible B.O.D.

The quantity of solids removed by primary sedimentation, as indicated by the difference in the suspended solids of the influent and effluent, was considerably less than the solids removed as indicated by the solids in the total volume of primary sludge. The higher solids content of the sludge is apparently due to the fact that it contains the additional solids washed out of the stock-washing equipment during periods of clean-up at the end of the week when the influent and effluent were not being sampled, plus extra stock from overflows and leaks which were immediately corrected when the waste was being sampled but which might remain unnoticed for a considerable period of time when samples were not being collected.

On the basis of the results obtained during 4 months' operation of the pilot

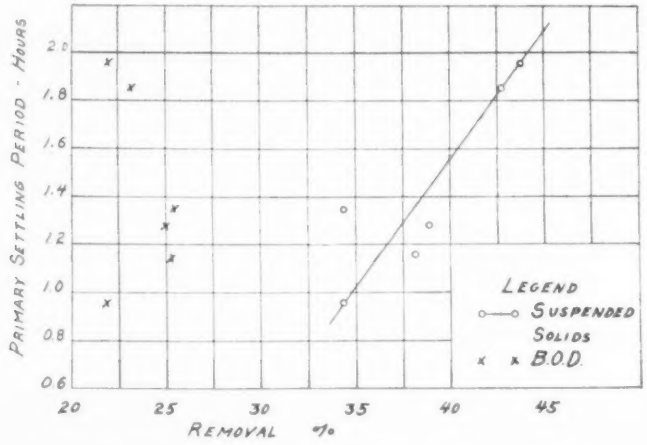

FIGURE 2.—Effect of primary tank detention period on removals.

plant, it appears that a suspended solids removal of 34 to 40 per cent, a B.O.D. removal of 20 to 25 per cent and a primary sludge volume of 1.25 to 2 per cent of the waste flow volume at a dry solids content of 8 to 10 per cent can be expected.

The B.O.D. and suspended solids removals are shown in graphic form (Figure 2) in relation to the sedimentation time in the primary tank. The effect of increasing the detention time from 1 to 2 hours is clearly indicated by increased suspended solids removals from 35 to 45 per cent, but there appears to be no relation between B.O.D. removals and detention time. This lack of change could be expected since most of the B.O.D. is in solution and the material which settled out after the first hour of settling is largely clay and carbonates that have no oxygen demand.

Secondary Treatment by Air Diffusion

The aeration tank was 12 ft. 6 in. by 20 ft. in plan with a total water depth of 10 ft. and was built as a small spiral flow tank. The settled waste and the returned sludge were fed in at the inlet end of the tank and the mixed liquor flowed out the other end over a weir extending across the full width of the tank. Air was diffused into the tank through a series of 24 $^3/_4$-in. perforated pipes installed along one side of the tank, 2 ft. above the bottom. The final settling tank was 8 ft. in diameter and was equipped with a motorized sludge collector similar to a conventional circular sedimentation tank. The sludge was returned to the inlet end of the aeration tank by the air-lift pump. When the suspended solids content of the mixed liquor exceeded the desired concentration, excess sludge was drawn off from the return line to a measuring barrel.

All data obtained in connection with the operation of the secondary treatment process by air diffusion for the 23-day period from October 13 to November 4 are summarized in Table II. Space limitations make it impossible to present similar data for other periods of flow; however, the complete data are available in the National Council's report on this project (4).

These data indicate that the process provides a practical means for the secondary treatment of deinking waste. Average B.O.D. removals of 68 per cent were obtained with an aeration period of 6 hr. and a return sludge flow of 35 per cent of the raw waste flow. It was indicated that this degree of B.O.D. removal would be sufficient to satisfy the local conditions. Consequently efforts were not directed toward securing a higher degree of removal but toward obtaining this indicated degree of removal at minimum cost.

TABLE II.—Secondary Treatment Summary Data; Period E—October 13 to November 4, Inclusive[1]

Average Flow (g.p.d.)	53,300
Aeration Period (hr.)	6.0
Final Settling Period (hr.)	1.02
Return Sludge Flow (g.p.d.)	18,800
Per Cent of Waste Flow (%)	35.3
Air Flow (c.f.m.)	120
Air Flow Rate (c.f./gal.)	3.24
Sodium Nitrate Added (p.p.m.)	10.4
Mixed Liquor	
Settleable Solids (%)	14.4
Suspended solids (p.p.m.)	6,200
Sludge Volume Index	23.3
Oxygen Demand (p.p.m./hr.)	8.6
Dissolved Oxygen (p.p.m.)	1.1
Waste Sludge	
Flow (g.p.d.)	1,442
Suspended Solids (%)	3.27
Final Effluent	
Suspended Solids (p.p.m.)	885
Volatile Solids (%)	20
pH	8.1
Turbidity (p.p.m.)	1,100
B.O.D. (p.p.m.)	169
Removal Raw to Final Effluent	
Suspended Solids (%)	63.7
B.O.D. (%)	68.1

[1] Characteristics of raw waste given in Table I.

The B.O.D. removal remained practically constant throughout the period of operation, with the aeration period varying from 6.0 to 11.4 hours. However, the suspended solids concentration in the mixed liquor was gradually increased as the aeration period was reduced. Further operation data would be required to obtain the independent effect of these two variable factors.

The successful operation of the plant at average mixed liquor suspended solids concentrations varying from 3200 p.p.m. to 6200 p.p.m. indicates that the process as applied to deinking waste will not be difficult to control. As long as sufficient air is supplied to maintain dissolved oxygen, only a minimum operation control will be needed to maintain the mixed liquor suspended solids within rough limits of concentration.

The volume of air used in the pilot plant work (3.24 cu. ft. per gal. of waste) is comparable to the quantity which would be required for treating sanitary sewage of equivalent strength (0.5 cu. ft. per gal. per 100 p.p.m. B.O.D. in the raw waste), but it should be possible to reduce this requirement in a commercial installation. In the pilot plant the efficiency of air absorption was extremely low because the diffusers were submerged only 8 ft. below the water surface and the slotted pipes were not as economical of air requirements as other diffusion equipment which breaks the air into finer bubbles. The question of improving the diffusion remains as a problem that must be investigated in later work.

The addition of approximately 12.5 p.p.m. of sodium nitrate to the settled waste was continued throughout the period of operation of the pilot plant, as the laboratory development work had indicated this as the optimum quantity (2).

The operation of the pilot plant did not produce a clear effluent. The high turbidities, averaging 1600 p.p.m., indicate why the effluent was not much different than the raw waste in appearance. The improvement after treatment is, however, readily apparent when the effluent is diluted with river water. The raw wastes maintain an apparent high turbidity with dilutions of 5 to 1, whereas the effluent turbidity is apparently greatly reduced with similar dilutions. It must be clearly understood that the operation of treatment plants similar to this pilot plant will not produce a trout stream effluent and that a sizable receiving stream will still be required to assimilate the remaining objectionable material in the waste.

Secondary Treatment by Trickling Filter

A trickling filter was operated in parallel with the diffused air treatment units during the last 3½ months that the pilot plant was in operation. The filter was 30 in. in diameter and 6 ft. deep with 2.5- to 3.5-in. stone chips as the filter media. The stone was confined with sheet metal side walls and adequate ventilation was provided for through the underdrains. Settled waste from the primary tank was discharged to the filter at intervals with a tipping bucket device.

The filter was operated at the relatively low feeding rate of 300,000 gal. per acre-ft. per day or 9.3 gal. per hour. This rate was used because of the high strength of the waste and because it was thought that ponding might develop because of the large amount of inert solids in the waste.

This rate of flow was held constant throughout the period of operation. There was no indication of ponding at any time the samples of the effluent indicated continuous sloughing. Sampling of the filter effluent was in parallel with other pilot plant sampling. All composite filter effluent samples were settled 1 hr. in an Imhoff cone before being analyzed so results would be comparable to those that could be

expected from a full scale plant with a final settling tank. During the first 56 days of operation there was no addition of a nitrate salt, but for the last 35 days sodium nitrate was added to the primary effluent at a rate of 12.5 p.p.m. so results would be directly comparable to the diffused air treatment.

The summary B.O.D. data for the two periods of operation are presented in Table III.

TABLE III.—Secondary Treatment by Trickling Filter

	Without Nitrate Addition	Sodium Nitrate Addition; 12.5 p.p.m.
Raw Waste B.O.D. (p.p.m.)	652	507
Primary Effluent B.O.D. (p.p.m.)	482	386
B.O.D. Removal Primary Treatment (%)	28	23
Settled Filter Effluent B.O.D. (p.p.m.)	358	295
B.O.D. Removal Complete Treatment (%)	46	42

The addition of sodium nitrate did not improve the B.O.D. removals, but since operations with and without the nitrate additions were not parallel there is no final proof that the nitrate was not of some value. The average B.O.D. removals were not sufficiently high in either period to meet treatment requirements for this waste, and there does not appear to be any reason to believe that this degree of treatment could be materially increased. Further work on the use of the trickling filter as a method of treating deinking waste is, therefore, apparently not justified.

Primary and Secondary Sludge Disposal

The disposal of the by-products of the treatment of deinking waste, the primary and excess secondary sludge, was one of the major problems to be solved in conjunction with the pilot plant studies. It had been impossible to work on this problem prior to the operation of the pilot plant because adequate samples of these sludges were not available and could not be made available in the laboratory studies. Work on this problem was started as soon as the pilot plant was under way and the results obtained are discussed in the following paragraphs.

Characteristics of Sludges

Primary sludge withdrawn from the primary settling tank averaged 8.8 per cent solids with a volatile content of 41 per cent. The average quantity withdrawn was 610 gal. per day or 1.58 per cent of the raw waste flow. The maximum variation in solids concentration of this sludge was from 6.6 to 12.1 per cent. The higher solids concentrations were ordinarily associated with a lower volatile content, indicating the presence of a higher proportion of clay in relation to the fiber content. Compaction of this primary sludge took place in a relatively short time and tests indicated that further compaction in concentration tanks would not be justified.

The secondary sludge withdrawn from the final tank averaged 1.82 per cent suspended solids and the average volume of 1790 g.p.d. was about 4.5 per cent of the total waste flow. Longer settling times than afforded by the pilot plant showed by laboratory tests that this sludge would compact to 4 to 7 per cent solids. One sample of secondary sludge from the final tank after being compacted for 24 hr. with the collector in operation, but without sludge return, had a solids content of 14 per cent. It is, therefore, obvious that the waste secondary sludge could be further concentrated after discharge from the final tank to reduce its volume to a minimum before being given further treatment. The data on the sludge held in the final tank for 24 hr. indicate that this sludge can be safely compacted for long periods and still be handled with conventional

pumping equipment. Based on the data available, a daily waste sludge volume of 1 per cent of the total waste flow at a solids content of 8 per cent would be a conservative estimate of the quantity of sludge resulting from a properly designed concentration tank.

Lagooning

Some preliminary data were obtained to indicate the land area required if the primary sludge were discharged direct from the primary tank to dump areas or to a lagoon. A small lagoon, with a maximum depth of 34 in. and a capacity of 786 gal., was dug adjacent to the primary tank.

Primary sludge was added daily for 6 days until the lagoon was filled and additional sludge then was added from time to time to keep it filled as the sludge compacted. The data obtained are shown in graphical form in Figure 3.

A total volume of 2521 gal. of sludge averaging 8.35 per cent solids and 43.7 per cent volatile solids was added to the sludge beds in 70 days and at the end of that time occupied a volume of only 786 gallons. At the end of 6 months this same sludge had further compacted to 669 gal., which is 25.5 per cent of the original volume. Samples from a sand bed indicate that after freezing and thawing, further compaction may result in a sludge of 50 per cent moisture content. At 50 per cent moisture content the theoretical volume of the sludge would be 16.7 per cent of the original volume.

The lagoon volume required for disposal of the primary sludge from a 1.0 m.g.d. waste disposal plant would be 3.7 acre-ft. per year for 6 months old sludge. After freezing and thawing, the volume required becomes only 2.43 acre-ft. per year. This volume is for primary sludge only and does not include space for the secondary sludge. An additional factor of safety should be figured in any estimate of required lagoon area to provide for winter operation when freezing and wet weather may temporarily interfere with the normal compaction rates.

No serious problems appeared in connection with the operation of the lagoon. At times there was an objection-

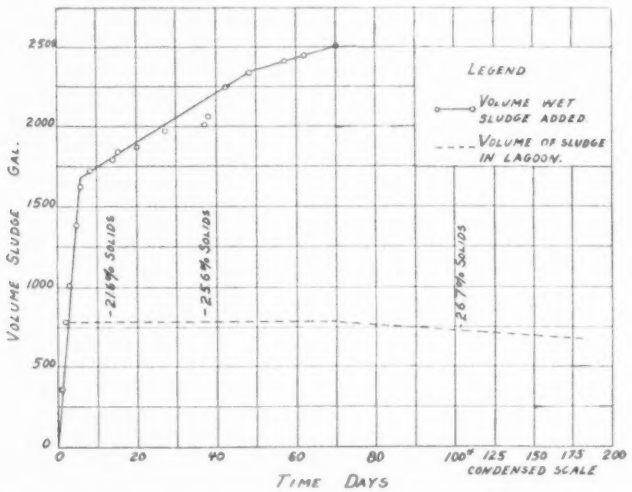

FIGURE 3.—Lagooning of primary sludge from treatment of deinking waste.

able odor from the sludge at the time it was discharged from the primary tank, but this odor carried only a few feet from the discharge pipe. The lagooned sludge had an exceedingly disagreeable sour odor when picked up by the hands, but this odor did not carry any appreciable distance. There was never any evidence of free gas production from the lagoon.

Vacuum Filtration of Primary Sludge

The vacuum filtration of primary sludge was considered as a possible alternate method of dewatering for locations where lagoons might be objectionable or where adequate lagooning land would not be available.

A 0.1 sq. ft. filter leaf furnished by Oliver United Filters was used with either fleece canvas or 50-mesh screen as the filtering surface, for determining filtering rates. Preliminary runs were made with No. 2 Whatman filter paper in Büchner funnels. All filtration rate data from the filter leaf studies were based on a filtration cycle of 25 sec. forming time, 50 sec. drying time and 25 sec. discharge and reentry time.

The primary sludge was successfully filtered as it came from the primary settling tank without the use of coagulants at filtering rates of 7.7 to 10.2 lb. of dry solids per square foot of filtering surface per hour. Well over 100 runs with a 50-mesh wire filtering surface were completed in connection with some sludge utilization studies, and there was no indication of any filter clogging.

Both the wire and the fleece canvas appeared to be satisfactory, although the cake broke away from the wire with less back pressure than it did from the canvas. The cake resulting from the filtration varied in dry solids content from 32.8 to 35.7 per cent. This is a cake which can be shoveled without difficulty and samples stored in the laboratory indicate there is no appreciable bacterial activity which would make the storage of the cake objectionable. Mold growth developed on the surface under high moisture conditions.

Vacuum Filtration of Secondary Sludge

Secondary sludge was concentrated overnight for all filtration studies so the sample used would be comparable to that which would be obtained from a secondary sludge concentration tank.

A satisfactory cake was not obtained without chemical coagulation but by the addition of calcium oxide to elevate the pH to 12.0 or above satisfactory filtering conditions were established. Typical data are shown in Table IV.

Fifty-mesh wire could not be used, but fleece canvas appears to be entirely satisfactory. Several hundred filtering runs were completed with secondary sludge coagulated with 15 per cent CaO (dry solids basis). Cake removal was completely satisfactory at all times and no cloth "blinding" was observed. The data indicate that vacuum filtration of secondary sludge will be successful when it is coagulated with 12 to 15 per cent CaO based on the dry solids content of the sludge, and a filter cake of 23 to 28 per cent solids can be expected at filtering rates of 14 to 24 lb. of dry solids per square foot of filtering surface per hour.

Vacuum Filtration of Mixed Primary and Secondary Sludge

The filtration of a mixture of primary and secondary sludges was also tried. Results were not satisfactory without chemical coagulants, but when 15 per cent $FeCl_3$ and 10 per cent CaO was added to the secondary sludge before it was mixed with the primary sludge, a satisfactory cake was produced on the 50-mesh wire. Two runs produced cakes of 31 and 33 per cent solids at filtering rates of 9.3 and 9.0 lb. of dry solids per square foot per hour. The mixture of the two sludges

TABLE IV.—Typical Data on Coagulation and Filtration of Secondary Sludge with CaO

Run No.	Sample*	Per Cent CaO of Dry Solids	pH	Filtrate (ml.)	Cake Solids (%)	Rate (lb./sq.f./hr.)	Cake Free of Filter Surface (%)
Büchner Funnel Filtration (one min.; Whatman No. 2 paper; 15-in. vacuum)							
1	A	10.7	12.0	34	24.0	—	100
2	A	13.0	12.4	46	30.4	—	100
3	A	7.2	8.8	4	—	—	0
4	A	9.0	9.5	5	—	—	0
5	A	0	7.6	2	—	—	0
Filter Leaf Filtration (25 sec. form; 50 sec. dry; fleece canvas; 15-in. vacuum)							
6	A	13.6	12.1	96	25.2	22.9	100
9	B	13.8	12.2	190	23.4	15.4	100
25	B	13.8	12.3	235	25.6	17.0	100
28	B	13.8	12.1	390	23.8	23.6	100

* Sample A: Total solids 14%; volatile solids 27% of total; pH 7.6. Sample B: Total solids 7.23%; volatile solids 31% of total.

after adding 15 per cent CaO to the secondary sludge was not tried, but it is entirely possible that this might be successful. It might then be practical to filter the combination on the wire as well as on cloth. This should be investigated in any future studies on filtration of these sludges.

Summary

A pilot plant for treating deinking waste biologically was built and operated during the summer of 1947 as a joint project of the Michigan Paper Company and the National Council for Stream Improvement. The plant was operated to obtain design and operating cost data and to determine if the process for treating deinking waste as developed in the National Council's laboratories at Kalamazoo College would be practical in the larger semi-plant scale size.

The operation of the primary sedimentation tank indicated that a suspended solids removal of 34 to 40 per cent and a B.O.D. removal of 20 to 25 per cent was obtained at detention periods of 1 to 2 hours. A sludge of 8 to 10 per cent solids content and a volume of 1.25 to 2 per cent of the volume of the raw waste was produced. The data further indicate that the removals obtained at a 1-hr. detention period were satisfactory for primary treatment of the waste preceding biological treatment. Where primary treatment is to be used alone without further treatment, a somewhat longer detention time should be considered.

Operation of the secondary treatment units indicated that the process was successful in removing 68 per cent of the B.O.D. with an aeration period of 6 hours. This has been indicated as being adequate treatment for deinking waste, under most existing conditions.

The addition of a nitrogen salt to improve the efficiency of treatment would present a sizable operation cost if continued throughout the year, but if used only during 4 months of the summer it would appear not to be prohibitive.

The effluent discharged to the river from the final settling tank was very turbid, averaging 1600 p.p.m. of turbidity. The turbidity is largely due to fine suspended clay which is not

deleterious to aquatic life, but the effluent will not differ appreciably in appearance from the raw waste. The effectiveness of treatment must, therefore, be judged on the basis of the analysis of the samples and not on the basis of visual observation.

The operation of a small trickling filter plant in parallel with the air diffusion treatment units indicated that B.O.D. removals of only 40 to 50 per cent could be obtained with the filter. On the basis of the limited data obtained, this method of treatment does not appear practical for deinking waste.

The operation of a small lagoon indicated that primary sludge can be discharged to a lagoon without creating a serious odor nuisance. In 6 months time or less the sludge will compact to 25 per cent of its original volume and after freezing and thawing there are indications that it will compact to about 50 per cent solids. At this moisture content it will support normal earth loads. The lagooned ground could thus be reclaimed for other uses.

Primary sludge was successfully dewatered on a vacuum filter to 32 to 36 per cent solids at filtering rates of 7.7 to 10.2 lb. dry solids per sq. ft. per hr. without the use of coagulants. At this solids content it can be readily shoveled and handled as a solid.

Secondary sludge was successfully filtered on a vacuum filter after coagulation with 12 to 15 per cent CaO based on the dry solids content of the sludge. A filter cake of 23 to 28 per cent solids was obtained at filtering rates of 14 to 24 lb. dry solids per sq. ft. per hour. Other coagulants tried were not satisfactory.

Acknowledgments

This project was carried on with the help and cooperation of Mr. R. L. Winget, Executive Secretary, and Dr. Harry W. Gehm, Technical Advisor, National Council for Stream Improvement, and of Dr. G. M. Ridenour, Associate Professor in Public Health Engineering, School of Public Health, University of Michigan. The construction of the pilot plant was carried on with the active help of Mr. Dwight Stocker, President of Michigan Paper Company, and his efficient staff; and laboratory work was carried on with the help of Kalamazoo College students and with the cooperation of Dr. Allen B. Stowe, Head of the Department of Chemistry, Kalamazoo College. The progress of the work was also greatly expedited by the loan of a blower by the Hoffman Machinery Corporation, 105 Fourth Avenue, New York, when it was impossible to buy such equipment; additional equipment which was used in the experimental work was loaned by Oliver United Filters, Inc., The Chicago Pump Company, and The Walker Process Equipment, Inc.

The author gratefully acknowledges the help provided.

References

1. Hodge, W. W., and Morgan, Philip F., "Characteristics and Methods for Treatment of Deinking Wastes." THIS JOURNAL, **19**, 5, 830 (Sept., 1947).
2. Morgan, Philip F., "Biological Treatment of Deinking Waste." *Paper Trade Journal*, **126**, 20, 41 (May 13, 1948).
3. American Public Health Association, "Standard Methods for the Examination of Water and Sewage," 9th Edition (1946).
4. Technical Bulletin No. 22, "Report on Methods of Treating Deinking Waste." National Council for Stream Improvement, 271 Madison Avenue, New York, New York.

LIMITS FOR TOXIC WASTES IN SEWAGE TREATMENT *

By Stuart E. Coburn

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An examination of the recent literature reveals a large number of articles describing the objectionable effects of various industrial wastes on sewage treatment. The factual evidence from these reports shows that these wastes have caused various troubles, from "excessive foaming" or "retarded digestion of sludge" to a complete breakdown of treatment plant facilities.

It is apparent that the deleterious effects of any industrial waste vary inversely with the dilution afforded by the sewage. Thus, the wastes from a certain industry in a small community might disrupt the treatment plant, whereas its effect in the sewage of a large city would be inconsequential.

Effects of Toxic Wastes

The objectionable effects of an industrial waste may be due to one or more of its various constituents. As an illustration, in the manufacture of mouton fur the following substances may cause trouble in treatment:

1. Grease and excess alkali from the scouring of the skins clog the sewers and retard biological treatment.
2. Heavy suspended solids both from the washing and the tanning overload primary treatment.
3. Toxic chromium from the mineral tan prevents digestion of sludge.
4. Large quantities of organic material having an excessively high oxygen demand overload oxidation processes.

Other wastes have their own characteristic effects. Tanneries, breweries, canneries, slaughter houses, textiles, rubber, metallurgical wastes, and numerous others, have different effects on sewage treatment.

Chromium salts, usually reported in the form of metallic chromium, have different effects on different units of a sewage treatment plant. The chromium is in the trivalent form in spent chrome alum in the wastes discharged from a tannery using a mineral tan. Chromium in this form will precipitate almost quantitatively in an alkaline solution such as sewage, and will be removed as sludge to digestion tanks, where digestion will be retarded or practically stopped. If secondary treatment is used there will probably be very little trouble biologically. On the other hand, if the chromium compounds are discharged from a plating establishment or from anodyzing of aluminum, the chromium is chiefly in the hexavalent form. Chromium cannot be precipitated under ordinary conditions in this form. Therefore, the effect on sludge digestion is very much less. However, in the hexavalent form the chromium is much more toxic, and when present in sufficient quantities will kill the organisms in filters or in activated sludge. The tolerance concentration is controversial. It has been reported to the writer that quantities up to 25 p.p.m. can be handled continuously. Edwards found that shock loads of about 40 p.p.m. slowed up nitrification and caused deterioration in the appearance of activated sludge

* Presented at Twentieth Annual Meeting, Pennsylvania Sewage and Industrial Wastes Assn., State College, Pa., August 26, 1948.

effluent. Information is still lacking as to the quantity of chromium which is permissible in sewage under the following variable conditions:

1. Type of chromium, trivalent or hexavalent.
2. Type of sewage treatment, such as primary and secondary.
3. Continuous flow versus shock loads over a period of a few hours.

Copper is a toxic substance easier to evaluate. As reported by Mohlman an excess of 1 p.p.m. has caused trouble.

Acid-iron wastes have caused trouble at Worcester, Fostoria, and in many other places.

Daily, weekly or monthly analyses have usually been reported. The question arises as to whether or not the trouble was caused by intermittent discharges of pickling liquors high in iron or acid content, or by a continuous discharge of wastes containing much smaller quantities of iron and acid. Zinc has been reported as detrimental to sludge digestion at Fostoria, Ohio.

Cyanides of 5 p.p.m. discharged continuously have an inhibiting effect on activated sludge treatment. Doses of 20 p.p.m. are reported as having an immediate effect on activated sludge, but after removal of the cyanide, the sludge recovers. Siebert reports that as low as 1 p.p.m. is toxic to biological activities. On the other hand, filtration of much higher concentrations of cyanide, through sand or coke breeze, has been suggested as a method of treatment.

From another point of view cyanides should not be permitted in sewage because of the slight possibility of acid wastes being present at the same time and therefore possible liberation of hydrocyanic acid.

Brewery wastes have interfered with sewage treatment at Jeanette, Pennsylvania. It was found during a recent investigation that the B.O.D. population-equivalent of the waste from a single brewery was greater than the population of the entire city.

Rubber wastes at Akron so overloaded the primary treatment units that the sewage plant reached its designed capacity long before the estimated time.

Substances such as acids, alkalies, silt, plasties, and grease, which cause localized troubles in a sewer, may also cause serious results at the sewage treatment plant.

Soluble cutting oils, while affecting treatment to some degree, are objectionable in that they pass through tanks unchanged and cause marked objectionable effect on the appearance of the receiving stream.

Control of Toxic Wastes

The writer takes the view that industrial wastes should be admitted to municipal sewer systems to the extent that they do not cause breakdown of the collection or treatment facilities either physically or biologically, or so overload the various units that the efflu-

TABLE I.—Concentration Limits for Toxic and Deleterious Wastes in Composite Sewage of Treatment Plant Influent *

Names of Items	Primary Treatment		Secondary Treatment
	No Sludge Digestion	Sludge Digestion	
pH index	5.0	6.5	6.5
Total iron (p.p.m.)	5.0	5.0	5.0
Copper (p.p.m.)	3.0	1.0	1.0
Chromium (p.p.m.)	5.0	5.0	3.0
Cyanide (p.p.m.)	2.0	2.0	2.0
Oils—mineral	Should be excluded by municipa ordinances.		
Oils—soluble	Removed to maximum practicable extent before discharge.		
Combustibles, etc.	Should be excluded by municipal ordinances.		
Free mineral acids	Should be neutralized at source.		
Acetylene generation sludge	Should be excluded by municipal ordinances.		

* Page 22, "Report—Proposed Collection and Treatment of Municipal Sewage and Industrial Wastes," Allegheny County Sanitary Authority (January, 1948).

ent is impaired to an objectionable degree. In other words, the presence of industrial wastes may cause temporary overloading and accompanying operational vexations, but pollution abatement is nearer being solved and the public better served by treatment of all wastes possible with the sewage in one plant, under the supervision of competent operators.

Whenever the proportion of wastes becomes so great that the sewage treatment plant becomes a wastes treatment plant, it is necessary for industry either to remove its wastes or to pretreat them to an acceptable degree. New sewage treatment plants may be designed to handle the industrial wastes of the municipality if their character and quantity can be predicted.

It is difficult but necessary that certain limitations be placed on the quantity of objectionable or toxic substances that may be present in sewage as received at the treatment plant. Such limits have been proposed by the Allegheny County Sanitary Authority. Table I has been taken from the Authority's recent report "Proposed Collection and Treatment of Municipal Sewage and Industrial Wastes."

It is the writer's opinion that if these concentration limits are met there will be no difficulty in treatment by the usual sewage treatment processes. In fact, it is probable that these limits can be exceeded manifold for short periods without any harmful effect.

A committee is needed to establish maximum limits of objectionable constituents of industrial wastes that are proposed to be treated with municipal sewage.

[*Note: A special sub-committee of the FSWA Research Committee was created for this purpose in 1948.—Ed.*]

NEW LIME BULLETIN ISSUED

The National Lime Association has recently published a 71-page illustrated technical book, known as Bulletin 213, entitled "Lime Handling, Application and Storage in Treatment Processes." This book should prove particularly helpful to those interested in the design, equipment, and operation of sewage and industrial trade waste plants, municipal and industrial water treatment plants, and any chemical process where lime is used as a coagulant, precipitant, or neutralizing agent. It constitutes a compilation of data on the principal methods of lime utilization in these fields; describes the types of feeders, slakers, hoppers, and solution pots; and presents the advantages and disadvantages of each type of equipment. Helpful pointers are given on the most efficient method of handling and feeding lime in dry or slurry form. Some related information is also given on other treatment chemicals.

Single complimentary copies may be obtained by writing directly to the National Lime Association, 927 Fifteenth Street, N.W., Washington 5, D. C. Additional copies can be purchased at 50¢ each plus postage.

Stream Pollution

INTERNATIONAL JOINT COMMISSION STUDY OF THE DETROIT RIVER *

By M. LeBosquet, Jr.

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Between the United States and our Canadian neighbor is an international boundary four thousand miles long. This boundary is virtually undefended and the two commonwealths have lived peacefully side by side for over a century. However, no two countries, any more than two States, can be expected to get along without occasional disagreement on mutual interests, including such matters as the quality and quantity of available water. To provide a systematic and equitable procedure for handling the friendly disputes of two good neighbors, there was negotiated a "Treaty Between the United States and Great Britain Relating to Boundary Waters, and Questions Arising Between the United States and Canada." This treaty was signed at Washington on January 11, 1909, and was ratified promptly by the Senate of the United States on March 3, 1909.

There are a number of sections of the treaty which are of interest in connection with the Detroit River. The preliminary article states in part that "Boundary waters are defined as the waters from main shore to main shore of . . . the international boundary . . . or the waters of rivers flowing across the boundary." Of somewhat greater interest is a section of Article IV, which states "It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other." Finally, the treaty creates an International Joint Commission to hear disputes and to conduct investigations itself or through agents.

There is remarkable similarity between the provisions of this treaty in regard to the control of pollution, enacted almost forty years ago, and recent enactments in regard to interstate pollution. Public Law 845, signed by the President June 30, 1948, reads in part as follows: "The pollution of interstate waters in and adjacent to any State or States . . . which endangers the health or welfare of persons in a State other than that in which the discharge originates is hereby declared to be a public nuisance and subject to abatement as herein provided." Similarly, the Ohio River Valley Water Sanitation Compact reads in part as follows: "Each of the signatory States pledges . . . the control of future pollution in and abatement of existing pollution from the rivers, streams and waters . . . which flow through, into, or border upon any . . . signatory States. . . ."

Survey of 1913

On August 1, 1912, the two governments referred the matter of pollution of boundary waters to the International Joint Commission for investigation, in a two-point reference: first, to determine if such waters were being polluted so as to be injurious to the

* Presented at Twenty-first Annual Meeting, Federation of Sewage Works Associations, Detroit, Mich., October 18, 1948.

public health and unfit for domestic or other uses and, second, to determine what remedies were possible and advisable. The actual work in connection with this assignment started in 1913, under the direction of a Board headed by Dr. Allen A. McLaughlin of the Public Health Service. Other members of the Board were Dr. J. W. S. McCullough, Chief Health Officer of Ontario, and Dr. John A. Amyot and Dr. F. A. Dallyn, both of the Ontario Board of Health. One man intimately connected with the 1913 survey is playing a prominent part in the survey now being conducted. This is Chemical Engineer A. V. DeLaporte, in charge of the Experimental Station of the Ontario Department of Health at Toronto. Following the field work in 1913, the International Joint Commission called upon a number of prominent engineers and scientists to assist in answering a series of questions. The list of engineers and scientists, which reads like "Who's Who in Sanitary Science," included names such as Fuller, Phelps, Whipple, Lea, Lafreniere, and Dallyn.

In reading over the various reports and proceedings of the 1913 survey, one is struck forcibly by the fact that the prime concern, almost to the exclusion of other factors, was with the question of bacterial pollution. One cannot help but reflect that in those days life was hazardous from the standpoint of water-borne disease to a vastly greater degree than it is today.

The 1913 International Joint Commission investigation on pollution of boundary waters created a great deal of interest and favorable reaction. It constituted one of the first times that waters in an extensive area such as from the St. Lawrence River to the Rainy River had been thoroughly investigated from the standpoint of pollution. Because of the extensive area covered, a total of eighteen laboratories was used in carrying out the work, ten laboratories being located in Canada, seven in the United States, and one on a U. S. revenue cutter. The total number of sampling stations used exceeded 1500, and the number of samples examined exceeded 18,000.

The conclusions of the International Joint Commission from the 1913 survey were submitted in a communication to the two governments on August 12, 1918. The Commission found that pollution existed in contravention of the spirit of the treaty, and concluded that "It is feasible and practicable, without imposing an unreasonable burden upon the offending communities, to prevent or remedy pollution both in the case of boundary waters and waters crossing the boundary." The Commission recognized that pollution was a continuing problem, and recommended that the International Joint Commission be given "ample jurisdiction to regulate and prohibit this pollution of boundary waters and waters crossing the boundary."

1946 Survey

From 1918 until 1946 there was no major activity of the Commission in connection with water pollution. One must conclude that either the water pollution problems of international boundary waters have not been sufficiently critical to cause the matter to be brought before the Commission or the local State and Provincial authorities cooperated to solve such problems as had arisen. In 1946 the matter of tastes and odors in the Detroit River was primarily responsible for a reference from the governments of the United States and Canada to the International Joint Commission, directing the Commission to "inquire into and report to the two governments upon the following questions:

"(1) Are the waters referred to in the preceding paragraph, or any of them, actually being polluted on either side of the boundary to the injury of

health or property on the other side of the boundary?

"(2) If the following question is answered in the affirmative, to what extent, by what causes, and in what localities is such pollution taking place?

"(3) If the Commission should find that pollution of the character just referred to is taking place, what measures for remedying the situation would, in its judgment, be most practicable from the economic, sanitary, and other points of view?

"(4) If the Commission should find that the construction or maintenance of remedial or preventive works is necessary to render the waters sanitary and suitable for domestic and other uses, it should indicate the nature, location and extent of such works, and the probable cost thereof, and by whom and in what proportions such cost should be borne."

This reference was dated April 1, 1946, and referred specifically only to the St. Clair River, Lake St. Clair, and the Detroit River. On October 3, 1946, the reference was amended to include the St. Marys River from Lake Superior to Lake Huron, including the important Sault Ste. Marie locks, and finally, on April 2, 1948, the reference was again amended to include the Niagara River from Lake Erie to Lake Ontario. This paper is concerned primarily with the Detroit-St. Clair River section of the broad survey activity.

Following receipt of the reference, the International Joint Commission called a meeting on May 15, 1946, at Montreal, at which discussions were held with personnel of the Canadian Department of Health and Welfare, the Ontario Department of Health, the U. S. Public Health Service, and the State of Michigan. The Commissioners at that time were Charles E. Stewart, Chairman, and Joseph E. Perrault, for the Canadians; and A. O. Stanley, Chairman, and Roger B. Mc-Whorter, for the U. S. Section. On the death of Mr. Stewart early in 1947, Mr. Perrault was appointed Canadian Chairman and George Spence was appointed as the second Canadian member. Early in 1948, Chairman Perrault died and the Canadian Section now has but one Commissioner.

Also present at the May 15, 1946 meeting were eight individuals who were later appointed to a Board of Technical Advisers. These included: for Canada, G. H. Ferguson and W. R. Edmonds of the Department of National Health and Welfare, A. E. Berry and A. V. DeLaporte of the Ontario Department of Health, and, for the United States, J. K. Hoskins and the writer, of the U. S. Public Health Service, John M. Hepler of the Michigan Department of Health, and L. F. Oeming of the Michigan Stream Control Commission. Mr. Hoskins and Mr. Ferguson were designated, respectively, as United States and Canadian chairmen. Following the retirement of Mr. Hoskins on January 1, 1948, L. M. Fisher was designated the U. S. Chairman for the remainder of the activity. The Board has met at monthly intervals, with few exceptions, starting in July, 1946, for the purpose of furnishing general technical direction of the activity. The actual field work is carried out by U. S. and Canadian technical staffs, working in close cooperation with State and Provincial pollution control authorities. The technical staffs from the two countries are quite separate but are in constant communication one with another and work in close cooperation, so that the final report will be a unified document.

Investigations of sources of pollution and of water uses are divided along national lines, the U. S. technical staff conducting this work on U. S. territory, and the Canadian technical staff conducting this work on Canadian territory.

Early in the survey activity, the U. S. and Canadian staffs reached

agreement on details of analytical methods, starting with the Ninth Edition of "Standard Methods for the Examination of Water and Sewage" in all cases and confining the work to these standard methods wherever possible. Likewise early in the investigation, agreement was reached in regard to sampling ranges, descriptions of sampling points, and numerous other details of operation.

The International Joint Commission survey is of considerable interest because of the number and character of the organizations furnishing cooperation during the activity.

Primary responsibility for the Canadian technical staff rests with the Canadian Department of National Health and Welfare. However, Mr. DeLaporte, of the Ontario Department of Health, directs staff activities. On the United States side, the technical staff consists of U. S. Public Health Service personnel.

The Royal Canadian Mounted Police Coastal Patrol, the U. S. Coast Guard, and the Corps of Engineers, Department of the Army, furnished sampling boats and crews. The Royal Canadian Air Force and the U. S. Air Force furnished film, planes and airmen for taking numerous excellent air photos in black and white and in color of the international waters under investigation. The Corps of Engineers and the U. S. Lake Survey furnished maps and navigation charts, flow records and assistance during float studies. The U. S. Geological Survey installed and operated tributary gauging stations as a contract service for the Public Health Service.

Assistance by the Province of Ontario and the State of Michigan has included the valued services of four members of the Board of Technical Advisers. In addition, the Province and State have made arrangements for industrial waste studies, have attended conferences, have assisted with municipalities, and have furnished valuable record information.

Municipalities have cooperated throughout, and the waterworks departments of Sarnia and Windsor, Ontario, and Detroit, Michigan, have furnished space for laboratories. These laboratory locations have been desirable, as the two staffs have been able to consult frequently with the waterworks operators and to be on hand when changes in water quality occurred.

The number of individuals on the two staffs has varied from time to time up to a maximum of six regular and six summer employees for the Canadian and 15 regular and two summer employees for the U. S. staff. A. V. DeLaporte, assisted by W. R. Edmonds, has directed the Canadian field staff. Hayse H. Black, succeeded by Ralph C. Palange, directed the U. S. field staff.

Special mention should be made of the consultation service, the more difficult analytical work, the work on the development of analytical methods, and the research conducted by the staffs of the Toronto Experiment Station and the Water and Sanitation Investigations Station at Cincinnati. Some of the most valuable findings of the International Joint Commission activity have resulted from activities of these two research organizations.

The work on the eighty-odd miles of the St. Clair River, Lake St. Clair and Detroit River was completed in August, 1948, at which time the laboratory activities terminated. During the active working period, from 60 to 80 samples per day from lakes, rivers, municipal intakes or industrial discharges, were examined. Approximately half of the samples were collected and examined by the U. S. Section and half by the Canadian Section. The total number of samples collected in the Detroit-St. Clair area from the start to the finish of the survey, by the two field staffs, was

12,000, on which some 60,500 individual determinations were made.

In studying industrial wastes in the area, it was the practice to hold conferences with industrial officials, securing all possible information in this manner, plus supplemental information available in State and Provincial files. A total of about 50 engineering studies and reports were prepared by the U. S. Section. In addition, on 23 of the critical industries—11 in the United States and 12 in Canada—where insufficient information was available from State and Provincial files, detailed sampling and gauging studies were made. The Canadian Section studied four industries and confined laboratory work to catch samples. During the U. S. industrial waste studies, the samples collected were divided between the Public Health Service laboratory, the State laboratory, and industry.

In connection with all industrial waste studies, the Board of Technical Advisers found it necessary to go to the International Joint Commission and obtain authority to receive confidential information with assurance to the industry that such information would be kept confidential, and authority also to release the industrial waste reports, when accepted by the Board of Technical Advisers, to the industry for its information.

The work on the Detroit River and the St. Marys River is now completed as far as field activities are concerned, and there remains the highly important activity of preparing a summary and report to the International Joint Commission. A limited staff, consisting of two engineers, a draftsman and a stenographer, is now maintained by the Public Health Service at Detroit, engaged in this activity. Canadian staff work on the report is proceeding at Toronto and Ottawa. While it cannot be stated definitely when the report will be completed, it should be noted that the U. S. appropriation, specifically designated for boundary waters pollution survey work in the Detroit area, will expire June 30, 1949.

The fourth question in the 1946 reference to the International Joint Commission has caused the Board of Technical Advisers considerable concern. The task of determining the nature and extent of remedial work for industrial wastes, as well as determining the probable cost thereof, would appear to be one of considerable magnitude. In order to secure information to assist in answering this particular question, as well as to serve many other purposes, hearings have been held before the Commission, at which hearings industry has been asked to supply the answer to the question. Most of the industries of the area have already been heard at hearings during June and September, at which it was revealed that the cost of facilities to correct industrial pollution will approximate $6,100,000. Additional hearings are planned for November, at which municipalities are to be the principal participants.

Statement of Objectives

The Board of Technical Advisers realizes that it would be less than reasonable to ask industries to present cost estimates without at the same time giving these industries some idea as to the objectives to be attained. Consequently the Board, early in 1948, drafted preliminary objectives, subject to change as the work continues. These tentative objectives were adopted by the International Joint Commission at its meeting in April, 1948, and were released at that time. A summary of the objectives is presented on page 831 of the September, 1948, issue of THIS JOURNAL, and the objectives are printed in full in the September 17, 1948 issue of the *Public Health Reports*.

While the objectives are stated largely in general terms, there are a few values which are of interest.

Keeping in mind that these are not final figures, the numbers are as follows: pH range of 5.5 to 10.6 in effluents; iron, 17 p.p.m. in terms of Fe in effluents; odor (threshold) 8 in the boundary waters due to added material; oil, 15 p.p.m. in effluents.

The objectives also contain a figure of 10 parts per billion in effluents, or 90 per cent purification in phenol or phenolic equivalents. The Board soon realized that this figure was unreasonably low, and the following statement was drafted and inserted in the minutes:

"Discussion has taken place in the Board as to whether the 10 p.p.b. phenol or phenol equivalent is too stringent. Communications from some industries have expressed opinions that the figure is too low.

"The Board takes cognizance of these opinions, but believes that in view of the preliminary nature of 'the statement of objectives' and the qualifications placed on the 10 p.p.b. phenol or phenol equivalent limitation, a change should not be made at this time. It is suggested that for the time being the 10 p.p.b. limitation figure serve as the basis for welcome discussion."

Analytical Methods

While the Board drafted a set of objectives which the Commission adopted, it was thought necessary also that the various constituents set forth in the statement of objectives should be defined. As a consequence, a committee on analytical methods was appoined and on October 6, 1948, the committee report was adopted by the Board of Technical Advisers and released to the public. The procedures included in the report are for iron, odor, oil, pH, and phenol.

Float Studies

Most of the lines of investigation pursued in the International Joint Commission survey of water pollution were of the nature of standard procedures, such as used in previous surveys. However, it is believed that the method of float studies used is somewhat unusual and that the taking of air photographs of water pollution situations is of considerable interest.

The float studies were important, as such studies should yield positive information on the course of pollution. Consequently, considerable study was made of previous float studies, and consultations were held with representatives of the U. S. Lake Survey Office and others. Two types of float studies were actually conducted. The first type was conducted by the Canadian staff using large submerged floats at various depths. This study was most important as it yielded information on currents below the effect of winds. The second type of float study was conducted by the U. S. staff using a great number of very small block floats. These small floats were ¾ in. by 2½ in. by 3½ in., and were painted orange, with the inscription lettered on as follows:

"PLEASE FORWARD TO U. S. PUBLIC HEALTH SERVICE, WATER WORKS PARK, DETROIT 14, MICHIGAN, THE SERIAL NUMBER OF THIS FLOAT, THE DATE, HOUR, AND ACCURATE DESCRIPTION OF PLACE AT WHICH FOUND, AND YOUR NAME AND ADDRESS. REPLACE THE FLOAT IN THE WATER."

These floats, numbered consecutively, were released at various points on the boundary waters and tributaries, a note being taken of all releases. The newspapers cooperated in a publicity campaign in connection with the float study.

The returns from the findings of these floats have been much greater than were expected. Since the start of the float investigation, 2880 floats have been released. As of September 30, 1298 observations have been reported, covering 958 floats. The

analysis of the data obtained from these reports will be a task of magnitude.

Conclusion

The International Joint Commission water pollution investigation of the boundary waters has been an activity directed by the Commission, and the results obtained as a result of the investigation will be reported back to the Commission. The Commission is the organization which will draw conclusions and make recommendations. The function of the Board of Technical Advisers, and of all the cooperating agencies, is to collect information and advise the Commission. The sanitary engineering profession will find it necessary to exercise patience in awaiting the final conclusions of the International Joint Commission. These conclusions will be submitted in final reports to the governments of the United States and Canada.

DETROIT RIVER STUDY—A DISCUSSION

By John M. Hepler

Director, Bureau of Engineering, Michigan Department of Health, Lansing, Mich.

When the Board of Technical Advisers started this survey, one of the first considerations was the types of tests to be run. Comparison with the 1913 survey was desirable where possible. Changes in water use and pollution should be noted. Time, however, made many comparisons impossible. In 1913 there were no "Standard Methods"; media for bacteriological examinations were different; coliform indices were reported as Phelps indices on the presumptive test; typhoid fever morbidity and mortality rates were the best indices of pollution; there were no determinations for phenol, cyanide, B.O.D., D.O. and pH. In fact, there was no industrial pollution—no chemical pollution. It was all bacterial pollution. As a result, the field staff was asked to make all the recognized tests for polluting material, and only after it was shown that certain tests would be of no value in the appraisal of the extent of pollution were they eliminated from the procedures. Partial elimination of the pH, alkalinity and chlorides determinations resulted from this procedure.

Specific techniques for determining the amount of a pollutant in the river water had to be developed from time to time. A "standard" test for a specific compound (such as phenol) would not be sensitive enough when applied to the river water where dilution or other interfering compounds existed. The technical staffs and past experiences of the Toronto Experiment Station and the USPHS Environmental Health Center were of great value in these matters. At the hearings recently conducted by the Commission in Detroit, one industry defended its refusal to supply data on the nature of its wastes on the grounds that there was no accepted test for such material.

Variations in technique affecting results were recognized and guarded against in many ways. An arrangement was made with Difco Laboratories to set aside a specific batch of bacteriological media so that all tests made in either the Canadian or U. S. Laboratories would be run with the same media. During one period of the survey the Canadian field staff did all sampling from shore to shore in the St. Clair River while the U. S. staff did the survey work on the Detroit River. Later the assignments were reversed so that any variations in sam-

pling, testing or interpreting results would be averaged or nullified. Another example was the procedure of dividing a specific industrial waste into three portions, sending one to the State laboratory, one to the industry, and one to the field laboratory, and later checking the findings before accepting and including them in the Industrial Survey Report.

Establishing ranges at the same or approximately the same locations as used in the 1913 survey should make certain comparisons with the earlier findings possible. Additional ranges to accommodate new sources of pollution or to confirm or disprove certain publicly accepted opinions were also needed. An interesting result of certain range studies when compared to available local data was the direction of attention to the Wyandotte waterworks intake. The bacteriological findings on the range samples could not be reconciled with plant records. A diver later confirmed the belief that a break existed in the intake.

The finding of a peculiar substance in a bottom sample from Lake St. Clair which, when tested in the laboratory, produced a taste similar to the one observed in the public water supply, started an unplanned investigation. Before it was finished the entire Red Run-Clinton River drainage system was surveyed.

Comment should also be made of some of the results of the survey to date. One has been the interest and cooperation of industry. Plants have been open for inspection; time of technical personnel has been given in collecting and sampling effluents, and in practically every case industry has not only accepted the staff findings as being the actual conditions, but in many cases plans have been made to correct conditions. Three industries discharging sanitary and process wastes at the time of the survey had completely eliminated such discharges by the time the hearings were held in June, 1948.

The newspapers have given the study excellent coverage with the result that the public not only is acquainted with what is going on but has developed a confidence in the Commission's purpose in connection with the reference. As a result, information relative to sources of pollution, its nature or, in the case of spasmodic types, its occurrence, has been received from many unexpected sources. This information has been volunteered purely in a spirit of cooperation. Sportsmen have been especially cooperative in noting and reporting conditions which may aid the Commission in reaching a complete appreciation of the problem. Especial mention should be made of the valuable assistance given by personnel of water departments and water plants located within the range of the survey. Records of the plants were made available; samples from the raw water intake were routinely collected; any appearance of taste and odor in the supply was immediately brought to the attention of the field staff and samples were collected and held for the staff. This cooperation was gratifying and of great assistance to the field staff.

The Board feels at this time that the material available and the data obtained are complete, and that when assembled and reported it will certainly indicate that the peak in pollution has been reached and that from now on improvement will be steady, measurable and satisfactory to all interested parties.

DETROIT RIVER STUDY—A DISCUSSION

By Earl Devendorf

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As indicated by Mr. LeBosquet a study of the pollution of the Niagara River has been referred to the International Joint Commission. The work of carrying on this investigation has only recently been organized and is planned to be carried out in a similar manner to that of the Detroit River studies.

A Board of Technical Advisers (consisting of personnel of the Canadian Department of Health and Welfare, the Ontario Department of Health, the U. S. Public Health Service and the New York State Health Department) has been appointed to assist in coordinating the studies. The Board has held three meetings with the technical staff assigned to carry on the field studies and to compile available information and operating data on existing industrial wastes and municipal sewage plant operations.

In carrying out the work, conferences are being held with municipal authorities and industrial officials and all available pertinent information obtained from state files has been made available. Detailed sampling and gaging stations are planned only where insufficient information is available, and at critical industries.

Of special significance and value in connection with the investigation of the pollution of the Niagara River is the recent study of the industrial waste problem of the Buffalo River. The results of this 3-year study have been reported by G. E. Symons in This Journal, **20**, 5, 861 (September, 1948). When this project becomes a fact, and the industries have reduced their waste load by the agreed amount, not only will nuisance conditions in the Buffalo River be abated but also the discharge of sludge of highly polluting taste-producing materials from the Buffalo River into the Niagara River will be greatly reduced, if not entirely eliminated.

Thus the results of this study and the program for reducing the pollution of the Buffalo River provides a major contribution to the study of the pollution of the Niagara River now under way by the International Joint Commission.

Pursuant to a joint resolution of the 1946 Legislature of the State of New York, the special Pollution Committee of the Joint Legislative Committee on Interstate Cooperation, of which Mr. Harold C. Ostertag is chairman, has made a study of the pollution of the waters of the state.

Based on a 2-year study of the problem, the committee prepared and introduced for study purposes an act creating a Water Pollution Control Board and integrating and coordinating the work of the two state departments, health and conservation, which now have divided responsibilities over the control of pollution. It is expected that this act, with any necessary amendments, will be presented for passage at the next session of the Legislature in 1949.

Accordingly, the completion and receipt of the report of the International Joint Commission on the study of the Niagara River will be awaited with interest by New York State and the municipalities and industries affected. The report will provide a method and means of appraising existing pollution sources in contravention of the treaty provisions, which will not only afford a basis of determining needed construction and stream pollution control correction, but will also provide a basis of cooperative action by the proposed State Water Pollution Control Board.

RELATION OF STREAM CHARACTERISTICS TO DISPOSAL OF CHEMICAL MANUFACTURING EFFLUENTS *

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This paper will present for the consideration of all those concerned with waste treatment and stream pollution abatement the point of view of adopting regulations based on capacities of the rivers for absorption as distinguished from specifications on the effluents themselves.

It is unlikely that any set of specifications for such wastes can be generally applicable because of the infinite variety in the character of some wastes and the great lack of precise knowledge of their composition. If, however, regulations were to be set up upon the extent to which streams may be used, a clearer and fairer problem would be presented to industry. The technical personnel of industry also would be able to visualize the waste treatment problems involved much more clearly. The diversity of wastes is so great that it is very likely that an equally great variety of treatment processes may have to be developed anyhow if industry is to help accomplish satisfactory stream improvement. It is believed that cooperation between industry and pollution control authorities will also be helped if the streams are looked upon as the realm of the state, and if stream studies are made to supply information currently lacking on the capacities of streams to absorb effluents. The work of state agencies would also be facilitated and simplified in the control of pollution.

Streams are more than mere moving bodies of water. They are also great reservoirs of dissolved oxygen and for the most part of acid neutralizing power. If each plant discharging effluents into a stream were permitted to use some modest percentage of such properties, the problems of waste treatment would become much easier to visualize and to solve. To allocate the use of small percentages of these stream capacities to industry, state authorities must be able to supply all the data and information on the stream itself. This means a thorough and comprehensive stream examination beforehand.

While there may be many capacities and characteristics of streams that might be considered for allocation, it is pertinent at this time to consider just two:

1. The capacity for absorbing oxygen consuming materials, or the dissolved oxygen content.
2. The capacity for neutralizing acid or alkalinity.

Dissolved Oxygen Content

Every river contains dissolved oxygen, which is depleted by some kind of pollution. Abatement of pollution can, to a considerable degree, be described as reduction of materials in wastes that require dissolved oxygen for their stabilization. The amount of

* Presented under title "Effluents from Chemical Manufacturing in Bound Brook," at Twenty-first Annual Meeting, Federation of Sewage Works Associations, Detroit, Mich., October 19, 1948.

D.O. a stream carries depends on the temperature of the water in the stream, and higher temperatures not only drive out oxygen but also increase the activity of oxygen-consuming agents. Warm weather and low flow, therefore, result in minimum dissolved oxygen. The determination of D.O. content is the critical measure of the extent of damage any given effluent may cause. The fixing of responsibility would seem to be clearer if the effect of industrial wastes upon the dissolved oxygen content of the river could be determined within a reasonable time and distance from the plant. The allocation of a certain reasonable amount of the dissolved oxygen content of a stream to each user would help the latter avoid excessive costs of treatment. Many factors would, of course, need to be taken into consideration in making such an allocation, especially the recuperating power of the stream itself.

The results of some pertinent tests and data on dissolved oxygen in the Raritan River are offered to support the thesis that a factory on a stream has a right to use some reasonable amount of the dissolved oxygen, and that the effect of the effluent may be measured by the reduction in D.O. content, which may be accurately and easily determined. In view of the lack of reliability of determining oxygen-consuming power, either with permanganate or by the 5-day B.O.D., efforts have been made to determine the effect upon the dissolved oxygen content of the river by direct D.O. determinations before and after receiving the effluent. Workers in one of the Calco laboratories have developed a polarographic method which has the advantages of speed, simplicity and freedom from interference by the presence of oxygen-consuming material in the river before or after receiving the effluent. This method will be described in a forthcoming publication.

Some representative Raritan River dissolved oxygen determinations in 1947 are shown in Table I. The locations of the sampling stations used are shown in Figure 1, in which the Johns-Manville and Calco plants are noted as A and B, respectively.

The effect of dilution by tide water begins at Landing Bridge. Three municipal sewage plants and four chemical factories discharge their effluents between Calco and Landing Bridge and, of course, there are even more discharges at New Brunswick.

The dilution ratios in Table I are not the minimum values recorded. Dilution ratios over a 6-year period are shown in Table II. It may be seen that it is very seldom that the dilution ratio is less than 10 to 1, the least dilution occurring in August and September, 1943; July and August, 1944; September, October, and November, 1946; and September and October, 1947. The river is very flashy, and

TABLE I.—Dissolved Oxygen in the Raritan River (p.p.m.)

	Sampling Station	Distance from Station 1 (miles)	Hours from Outfall	June, 1947				July 3
				17	18	19	25	
River above plant	1	0	—	8.2	7.2	8.2	8.6	7.2
Effluent dilution ratio*	—	—	—	30	24	28	20	14
Below outfall of effluent	2	0.19	0.2	7.9	6.8	7.9	7.6	6.8
South Bound Brook Bridge	3	1.6	3.0	7.3	5.8	6.5	6.7	4.6
Landing Bridge	4	6.8	13.4	6.8	3.7	4.5	4.5	1.5
Albany Street Bridge	5	8.4	16.6	6.8	3.3	3.3	4.2	0.6
Tide going	—	—	—	In	Out	Out	Out	Out

* Volumes of river water per one volume of effluent.

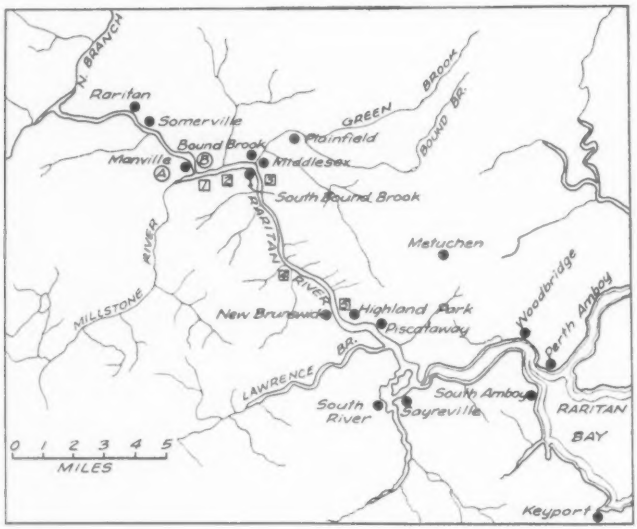

FIGURE 1.—Raritan River, showing location of sampling stations.

TABLE II.—Average Effluent and Raritan River Flows (m.g.d.) and Dilution Ratios

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1942												
Effluent	18.6	20.5	21.2	22.8	25.5	25.6	25.0	24.0	23.9	19.0	16.6	15.6
River	333	372	1060	485	223	176	264	2070	641	416	560	1150
Dil. Ratio	18	18	50	21	8.7	6.9	10.5	86	27	22	34	74
1943												
Effluent	17.3	19.4	18.8	18.9	19.8	22.6	23.4	22.7	23.4	19.2	17.8	17.8
River	636	1110	867	460	870	335	314	95	76.2	405	775	234
Dil. Ratio	36	57	46	24	44	15	13	4.2	3.25	21	43	13
1944												
Effluent	18.9	22.0	20.8	20.5	22.3	24.7	24.2	22.5	24.2	20.7	20.1	18.7
River	1059	561	1446	1305	446	310	91	41	470	98	778	874
Dil. Ratio	55	25	70	64	20	12.5	3.7	1.8	19	4.7	39	47
1945												
Effluent	19.4	18.1	19.1	19.8	21.9	22.0	22.5	18.7	21.5	20.1	18.9	16.3
River	740	1780	1467	632	1087	446	1212	782	903	346	1050	1439
Dil. Ratio	38	97	77	32	50	20	54	42	42	17	55	89
1946												
Effluent	17.5	17.1	17.9	19.0	19.5	20.6	21.7	20.1	20.1	21.5	20.0	18.0
River	1095	539	1363	424	1078	1430	837	349	188	158	137	304
Dil. Ratio	62	32	76	22	55	69	38	17	9.3	7.3	6.8	17
*1947**												
Effluent	19.0	20.2	21.2	20.6	21.7	21.6	24.6	24.5	23.6	22.5	22.7	18.7
River	786	432	1051	1041	1538	780	387	314	199	137	1410	475
Dil. Ratio	41	21	51	50	71	36	16	13	8.4	6.1	62	25

* Data for 1947 are U.S.G.S. river flows at Calco's dam. Earlier figures are calculated from staff gage readings.

may show wide variations in flow. Table III shows maximum and minimum flows in million gallons per day. However, critical periods occur only when long-continued deficiency of oxygen extends over a month or more.

Dissolved Oxygen Content and B.O.D.

Studies made by Dr. Willem Rudolfs and Dr. H. Heukelekian at the New Jersey Agricultural Experimental Station showed that the B.O.D. of Calco's

effluent varies with the dilution in the range of low or inadequate dilutions, with a lag phase at low dilution which results in less demand than at a somewhat higher dilution. With plenty of dilution the effect on the stream is less, even though the full deoxygenating effect of the waste has been developed. Laboratory experiments were undertaken to study this unusual condition, as compared with the normal B.O.D. of sewage.

Two sets of B.O.D. tests were run on the effluent, in the first of which dilutions of 1 : 6, 1 : 15 and 1 : 60 were used and in the second, 1 : 6 and 1 : 15. The water for the 1 : 6 dilution in the first experiment was aerated with pure oxygen, giving 25.9 p.p.m. in solution. In the second test, air-saturated water with an initial D.O. content of 7.2 p.p.m. for the 1 : 6 dilution was used, and this dilution was reaerated after 2, 3, and 4 days, while the initial D.O. was 8.1 for the 1 :15 dilution and this was reaerated only once, after 2 days. Results are given in Tables IV and V.

Deoxygenation

The oxygen utilized in the closed system by the 1 : 6 dilution was low the first and second days, increased sharply on the third day, and then more or less leveled off. Similarly, with the 1 : 15 dilution, the oxygen utilized in the first test was low for the first two days, increased on the third and fourth days, and the water was completely depleted on the fifth day. On the basis of the diluted samples, the oxygen utilized in the 1 :15 dilution was lower than in the 1 : 6 dilution, and in the 1 : 60 dilution it was lower than in the 1 : 15 dilution. When the results are calculated on the basis of undiluted plant effluent, there is an increase of B.O.D. with dilution. The lowest B.O.D. was obtained with 1 : 6 dilution and the highest with 1 : 60. The 1 : 15 dilution gave results closer to the 1 : 6 than to the 1 : 60. This indicates that in the range of low dilutions it is not correct to refer to the B.O.D. of the plant effluent without specifying the dilution.

In the second test only 1 : 6 and 1 : 15 dilutions were used (Table V). Dilutions were made with water from the North Branch of the Raritan River after the silt was removed by storage.

The oxygen utilized by the 1 : 6 dilution was extremely low the first day, increased on the second day, and reached a peak on the third day. Although additional quantities of oxy-

TABLE III.—Maximum and Minimum Flows in Raritan River (m.g.d.)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1942												
Maximum	1260	3050	4720	1415	600	499	1350	11,000	5660	1800	2860	6610
Minimum	172	141	141	141	95	75	115	141	141	176	176	176
1943												
Maximum	2720	3800	5510	1415	5220	1415	1000	275	241	3735	5290	1540
Minimum	206	408	141	319	206	108	95	26	26	38	229	93
1944												
Maximum	5900	3300	5900	5320	1000	1000	148	169	3170	349	4900	3855
Minimum	148	148	333	496	187	99	41	4.9	2.9	18	55	323
1945												
Maximum	6710	10,000	4450	2120	4900	1551	7000	3005	4326	614	6650	5954
Minimum	220	177	500	352	408	181	162	239	178	207	165	421
1946												
Maximum	5945	1551	5784	778	6915	13,800	6524	891	905	301	213	2400
Minimum	372	359	561	232	226	206	129	187	76	116	103	65
*1947**												
Maximum	2880	826	3530	4120	4110	2340	865	1200	450	570	6850	1338
Minimum	260	320	308	440	550	332	114	128	121	80	298	276

* Data for 1947 are U.S.G.S. river flows at Calco's dam. Earlier figures are calculated from staff gage readings.

TABLE IV.—Deoxygenation of Plant Effluent in Closed System with Various Degrees of Dilution with Seeded Synthetic Dilution H_2O

Days	1 to 6 Dilution			1 to 15 Dilution			1 to 60 Dilution		
	D.O. (p.p.m.)	D.O. Utilized (p.p.m.)	B.O.D. (p.p.m.)	D.O. (p.p.m.)	D.O. Utilized (p.p.m.)	B.O.D. (p.p.m.)	D.O. (p.p.m.)	D.O. Utilized (p.p.m.)	B.O.D. (p.p.m.)
Initial	25.9	—	—	7.4	—	—	7.4	—	—
1	24.2	1.7	10.2	6.4	1.0	15.0	6.8	0.6	36
2	22.2	3.7	22.2	6.3	1.1	16.5	6.0	1.4	84
3	13.5	12.4	74.4	5.0	2.4	36.0	5.3	2.1	126
4	12.9	13.0	78.0	1.0	6.4	96.0	4.6	2.8	168
5	9.9	16.0	96.0	0	7.4+	111.0+	3.8	3.6	216

TABLE V.—Deoxygenation of Plant Effluent in Closed System with Various Degrees of Dilution with River Water

Days	1 to 6 Dilution			1 to 15 Dilution		
	D.O. (p.p.m.)	D.O. Utilized (p.p.m.)	B.O.D. (p.p.m.)	D.O. (p.p.m.)	D.O. Utilized (p.p.m.)	B.O.D. (p.p.m.)
Initial	7.2	—	—	8.1	—	—
1	7.0	0.2	1.2	7.6	0.5	7.5
2	4.9	2.3	13.8	1.8	6.3	94.5
2*	7.5	—	—	7.7	—	—
3	0.1	9.7	58.2	5.2	8.8	132.0
3*	7.2	—	—	—	—	—
4	3.9	13.0	78.0	3.2	10.8	162.0
4*	7.5	—	—	—	—	—
5	4.6	15.9	95.4	0.8	13.2	198.0

* Reaerated

gen were utilized on the fourth and fifth days, the amount decreased. In the 1:15 dilution, the rate was also low on the first day, but reached a peak on the second day, while the rate decreased thereafter. It is worth noting in this test that the 1:15 dilution actually used more oxygen on the first and second days than the 1:6 dilution. The 1:6 dilutions in the two tests were similar to each other in respect to the attainment of the peak rates and magnitudes of oxygen utilization.

These tests indicate that, excluding reaeration, the greatest tax on the oxygen supply of the river will be with a flow time of 3 days when the dilution ratio is 1:6, and 2 days with a dilution ratio of 1:15. After a flow time of 2 days, the deoxygenating effect of the effluent will be greater when the dilution in the stream is 1:15 than with a lower stream flow. At this dilution the velocity of the stream will be somewhat higher and the maximum deoxygenating effect will be felt somewhat farther downstream.

These data show an inhibition of deoxygenation at low dilutions, and the existence of a lag of 1 or 2 days at 1:6 and 1:15 dilutions before the maximum rates of deoxygenation are exerted. Theoretically, the inhibition with increased concentration and the initial lag with time mean that the usual monomolecular formula employed for the deoxygenation of sewage does not apply to this waste. Therefore, it will be useless to derive the velocity constant k_1 of the reaction

on the basis of this formula. The monomolecular formula assumes the oxygen demand exerted is dependent upon the amount of oxidizable material remaining to be oxidized; that is, the greatest oxygen demand is exerted in the first unit of time. Table V shows that the rate is not constant and the least demand is exerted during the first day. Somewhere between 1:6 and 1:60 dilution the inhibiting effect is overcome, and the maximum rate of deoxygenation is exerted in the first day. At 1:60 dilution the net effect on the D.O. content of the river will be smaller than at 1:15 or 1:6.

Practically, the inhibition caused by greater concentrations of the effluent on the deoxygenation rate means the dissolved oxygen levels in the stream will be maintained for a flow period of 1 or 2 days under low flow conditions, which would otherwise not be possible.

The results also indicate that the deoxygenation is primarily of a biochemical nature, although the possibility of a small amount of chemical oxidation exists. A purely chemical oxidation would have an immediate oxygen demand as compared with a delayed B.O.D.

In addition to being a mass of moving liquid and a reservoir of dissolved oxygen, rivers also constitute a reservoir of acid neutralizing power. How far shall such neutralization of acid wastes be carried? Is it necessary to neutralize everything, including CO_2, to pH 7 or can better or equally beneficial results be obtained at much less cost by determining just how far neutralization should in each case be carried? An arbitrary decision to neutralize everything completely not only puts the maximum burden on industry, but it may be questioned whether it is the best from the pollution abatement point of view.

Many rivers themselves are alkaline and capable of neutralizing various tonnages of acids. Does industry have the right to use some reasonable percentage of such acid neutralizing power? It is quite conceivable that a given river could absorb a determinable amount of acids throughout its length without any damage to the river at all, and that if the various industries along that river were permitted to utilize some part of that power, much expense would be saved.

Aside from cost, neutralization to complete neutrality may be very difficult to carry out and may even be detrimental. We have shown that sanitary sewage can be completely sterilized by contact with acid effluents, and that if neutralization is carried to pH 4 and not farther, no *B. coli* escape with the effluent. This in itself is important because it may enable industry to avoid the cost of separate sewage treatment.

It has been frequently stated that neutralization to pH 4 neutralizes all mineral acids as distinguished from organic acids; the writers believe that in the range 3.5 to 4.2 all mineral acids are neutralized.

In a laboratory investigation of the subject, solutions of sulfuric and acetic acids were made up to simulate the effluent in dilutions of 0.005 N and with different proportions of mineral and organic acid. These solutions were neutralized with the following results:

As H_2SO_4 (%)	90	50	10
As acetic (%)	10	50	90
Mineral acidity neutralized at pH 4.0 (%)	98	112	133
pH at which 100% of mineral acidity is neutralized	4.17	3.71	3.51

As the Calco effluent is not believed to contain 90 per cent mineral acids, it appears that all mineral acidity is neutralized in the effluent even below pH 4.

TABLE VI.—Calculated Acidity of Calco Effluent at pH 2.0 to pH 4.0

pH	H-ion Concentration	Normality	Total Acidity as H_2SO_4 (p.p.m.)	Equivalent Mineral Acidity (tons H_2SO_4 per day*)
4.0	10^{-4}	0.000100	4.90	None
3.75	$10^{-3.75}$	0.000178	8.74	0.384
3.69	$10^{-3.69}$	0.000204	10.0	0.510
3.5	$10^{-3.5}$	0.000316	15.5	1.060
3.0	$10^{-3.0}$	0.001000	49.0	4.410
2.0	$10^{-2.0}$	0.010000	490	48.510

* Based on 200,000,000 lb. effluent per day.

Table VI shows the calculated acidity and mineral acidity of Calco effluent as a function of pH.

Figures in the last column of Table VI are calculated on the basis of complete neutralization of all mineral acidity at pH 4.0. Table VII shows the calculated acid neutralizing power of the Raritan River.

The use of but 5 per cent of the river's acid neutralizing power would permit the discharge into it of an amount of effluent containing the equivalent of from 1.67 to 11.12 tons of H_2SO_4 per day, or an average of 5.22 tons per day. During 220 working days this would save about 1150 tons of calcium carbonate (neutralizing agent) per year.

TABLE VII.—Acid Neutralizing Power of the Raritan River (1946)

	River Flow (m.g.d.)	Average Alkalinity as $CaCO_3$ (p.p.m.)	Acid Neutralizing Power in Tons H_2SO_4 Per Day
January	1095	30	134.3
February	539	34	74.5
March	1363	26	145.0
April	424	41	71.5
May	1078	41	180.3
June	1430	38	222.5
July	837	49	167.6
August	349	55	78.4
September	188	52	40.2
October	158	56	36.3
November	137	59	33.3
December	304	54	71.5

It is believed that industry can be spared much expense in the cost of neutralizing waste acids if some small percentage of the acid neutralizing power of the stream employed to receive the effluent may be used. The extent to which permanent hardness is increased, the number of actual and potential users among whom the acid neutralizing power must be apportioned, the ability of the stream to reacquire acid neutralizing power, etc., are all points that would have to be weighed in preparing such a regulation, but appropriate studies could lay the foundation.

Calco Waste Treatment Facilities

The Calco waste treatment process and plant have been described previously (THIS JOURNAL, **14**, 3, 666; May, 1942). The following information and data cover changes and developments since 1941.

Oxygen-Consuming Wastes

A survey of the plant revealed that a large part of the oxygen-consuming materials came from processes discharging brines containing sulfur compounds. Some of these individual effluents had permanganate oxygen-consuming powers as high as several hundred thousand p.p.m., depending upon how the analysis is made. It was found by laboratory and pilot plant investigation that most of this oxygen demand could be destroyed by first oxidizing all of the sulfides, polysulfides and sulfhydrates under proper pH control to thiosulfates, polythionates and the like, by blowing the liquors with air, followed by stripping with waste sulfuric acid and heat to precipitate sulfur and liberate and remove sulfur dioxide. This treatment was very effective.

However, the aeration step had its faults. It did not entirely prevent hydrogen sulfide odors; it took a long time to air out some of the liquors,

and the acidification was destructive to equipment. Because of this, the aeration is now being superseded in part for many liquors by an acid-thiosulfate-sulfide treatment which does not liberate any hydrogen sulfide odor and takes much less time than aeration. While the new process does not reduce the oxygen demand quite as much, it does remove more than two-thirds of the oxygen consumers, and the following hot waste acid treatment removes even more, so that reductions from 100,000 p.p.m. to well below 5000 p.p.m. of individual wastes can be accomplished.

The process consists of the following steps:

1. Collection of all brines that contain sulfides, polysulfides, sulfhydrates, thiosulfates and similar oxygen-consuming chemicals from the various sometimes widely seperated shops that produce them.
2. Compositing of these liquors.
3. Mixing weak waste sulfuric acids with brines containing chiefly thiosulfates but little or no sulfides, polysulfides or sulfhydrates to pH 2.5 to 3.0. This liquor loses some SO_2 and contains, it is believed, free thiosulfuric acid as well as SO_2.
4. Feeding the composite to the acidified thiosulfate, maintaining the pH with more waste sulfuric, which precludes any liberation of H_2S and produces a liquor containing precipitated sulfur and acidified thiosulfate.
5. Complete acidification to pH 1.8 and heating to complete the precipitation of sulfur and removal of SO_2.
6. Settling sulfur in pits.

The sulfide brines are collected and delivered by tank truck to the waste treatment plant serving the sulfur color shop (Figure 2). All sulfur color effluents, which are rich in both sodium sulfide and sodium thiosulfate, are pumped directly to a collecting and compositing tank where they are mixed with other sulfide brines collected by tank truck. A typical approximate analysis of such a composited brine is as follows:

	$Na_2S_2O_3$	Na_2SO_3	Na_2S	NaOH	O.C.P.*
Grams/100 ml.	17.2	0.72	3.27	3.06	—
P.P.M.	—	—	—	—	64,800

* Total apparent chemical oxygen-consuming power determined by digestion with hot permanganate (30 minutes).

To destroy oxygen-consuming power, sulfides are converted to thiosulfates and the dilute solution is acid stripped to remove SO_2. Conversion of sulfides to thiosulfates is accomplished in two ways. Brines that are low in sulfide that can be conveniently aerated are blown with air, with oxidation of sulfide to thiosulfate. However, with even a brine of the above sulfide content, aeration becomes tedious and expensive. To circumvent this operation, an already aerated brine is made acid with waste sulfuric acid and the SO_2 liberated from the thiosulfate is used to convert more sulfide to thiosulfate according to the following equations:

$$Na_2S_2O_3 + H_2SO_4 = Na_2SO_4 + H_2O + SO_2 + S$$

$$2Na_2S + 3SO_2 = 2Na_2S_2O_3 + S$$

This is done in our present equipment by aerating in one tub and transferring the aerated batch to a second tile-lined tub, filled to one-half its capacity. Waste acid is added to a pH of 2.5, and an equal volume of raw sulfide brine is run in under the surface with the addition of enough extra acid to hold the pH approximately constant. Sulfides are smoothly converted to thiosulfuric acid under these conditions, and a mixture containing free SO_2 and presumably thiosulfuric and some polythionic acids is obtained. One-half of this mixture, which now has an oxygen-consuming power of approximately 20,000 p.p.m., is retained for treating more sulfide brines and the second half is further acidified

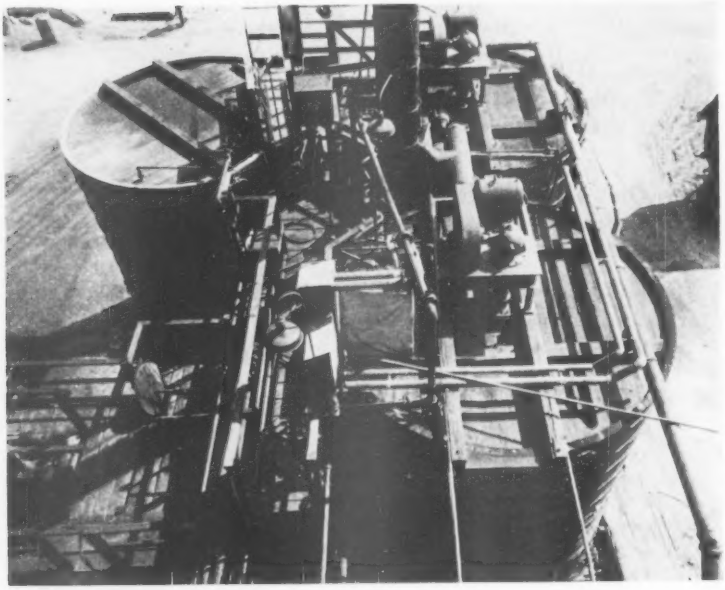

FIGURE 2.—Treatment at the source plant for sulfide brines.

with waste sulfuric and heated to the boil to drive off all SO_2 and reduce the oxygen-consuming power, as measured by hot permanganate, to a minimum. This will run in the neighborhood of 4000 p.p.m., and is believed due almost entirely to stable polythionic acids which actually do not consume oxygen in the river. It is also colorless, and in this treatment at the source all the colored brines of this class are completely decolorized.

While waiting for the construction of suitable sulfide-brine holding capacity for carrying out this procedure to completion, one treatment tub is temporarily being used to collect and, when necessary, to aerate sulfide effluents, and a second to carry out the SO_2 treatment. One-half of each treated batch is temporarily being discharged to the main effluent and the second half used in treating more waste. Following are the analyses for three consecutive batches treated in this way; thiosulfuric acid and free SO_2, which are assumed to be present, are calculated as sodium thiosulfate and sodium sulfite, respectively:

$Na_2S_2O_3$ (mg./100 ml.)	Na_2SO_3 (gm./100 ml.)	O.C.P.* (p.p.m.)	pH
4.93	0.1	22,100	3.3
7.46	0.15	20,300	3.2
7.08	0.0	28,700	3.1

* Oxygen-consuming power.

Other Wastes

Other treatments at the source consist of recovery plants, notably for alcohols, pyridine, aniline and others. Aniline is especially bad as it has a permanganate oxygen-consuming power of twice its own weight. The sludge from aniline manufacture was formerly run to the treatment plant as is. Now this waste is run into two large basins where the sludge settles out

and the liquor percolates into the ground. In addition to having a very high permanganate oxygen-consuming power, this waste also caused a reddish tinge in the composited wastes due perhaps to partial oxidation of very small quantities of aniline.

Oils escaping from the refining of coal tar products are trapped in various basins and removed by means of skimmers so that they no longer reach the treatment plant. These oils also had a high chemical oxygen-consuming power and were frequently emulsified in such a manner that they could not be removed from the composited wastes by skimming. They also contributed to the formation of foams at the diffusion dam.

Other treatments at the source, which are contemplated for the future, are changes in manufacture so that there will be no wastes from certain products. This will remove certain sulfonic acids, mixed with oily material, which are troublesome because they produce foams and have high oxygen-consuming powers.

The SO_2 recovery plant where large amounts of SO_2 are recovered from waste sulfite brines, has long been one of the chief tools for reducing oxygen-consuming power in the general effluent. As an added precaution against any increase in oxygen-consuming power which might be brought about by new products, the recovery system is being improved by first making more sulfite brines available from three large processes and by enlarging the SO_2 recovery plant itself. This should reduce the B.O.D. of the effluent another 30 p.p.m., and will also consume more waste acids.

Individual collecting tubs have been installed at certain places where liquors are collected for treatment at the source and where it is inadvisable to discharge strongly acid or highly colored mother liquor to the sewer at a high rate of flow. Some highly colored mother liquors may be decolorized by lime treatment at the source, and after settling and decanting the resulting liquors do not reproduce color upon being absorbed in the composite effluent.

In addition to an effective treatment for reduction of chemical oxygen-consuming power or B.O.D., these treatments at the source are essential for the proper operation of the waste treatment plant. The mother liquors or filtrates from any new process are investigated carefully in the laboratory before that process is started in order to determine what effect such liquors might have upon the effluent. When the liquors are undesirable, their treatment at the source is investigated and the treatment modified so as to produce a better effluent.

Compositing

The compositing basin is the heart of the Calco waste treatment process. Here many beneficial reactions take place: color and acidity are reduced, bacteria are destroyed, and suspended solids settle out. Accumulation of this sludge during 6 years reduced the capacity and impaired the efficiency of the basin. In order to regain the benefits of efficient compositing, the sludge was removed by dredging as described later.

Neutralizing Acidity

Calco is indebted to its neighbor, the Johns-Manville Corporation, for an additional supply of alkaline material for use in neutralizing acid wastes. This is saturated lime water containing some suspended calcium carbonate. There are 700,000 gal. of it, equivalent to 7.5 tons per day of calcium carbonate. This is brought over by gravity through a 24-in. Transite pipe line about a mile long. The lime water flows continuously into the compositing basin and partially neutralizes the effluent just prior to the final neutralization with the $CaCO_3$ slurry and discharge from the compositing basin.

The waste calcium carbonate slurry is brought from this neighboring plant at a cost of about 55¢ per ton, to neutralize the mineral acidity of the composited effluent. Since the alkaline water described above has also been used, it is rarely necessary to draw upon the reserve supply of accumulated calcium carbonate. This has saved considerable labor and has insured a smoother operation of the neutralizing apparatus. Coarse grit is classified out of the $CaCO_3$ slurry to avoid its interfering with neutralization by plugging orifices and valves.

The final neutralization of the discharge from the compositing basin (Figure 3) is very rapid, and the calcium carbonate slurry containing some bicarbonate can be fed in readily.

Settling Lagoon

The neutralized effluent flows into the settling lagoon where the suspended solids are deposited as a sludge during detention in the lagoon.

Under current operation, tests show that 4 tons of sludge (dry basis) settle out daily in the compositing basin and 6 tons settle out daily in the settling lagoon. As a result the capacity of the compositing basin was reduced. A dredge was constructed to remove this material so that the basin might regain its full efficiency. In 3 months, 44,000 cu. yd. of water and sludge were removed from this basin by dredging at a cost of about 35¢ per cubic yard. When the sludge was removed, compositing was improved to such an extent that the shock of discharges of strong individual wastes was minimized. In addition to the 44,000 cu. yd. of sludge and water removed from the compositing basin, about 140,000 cu. yd. were subsequently removed from the settling lagoon.

Character and Decomposition of Settled Sludge

In order to obtain some information regarding the character and degree of

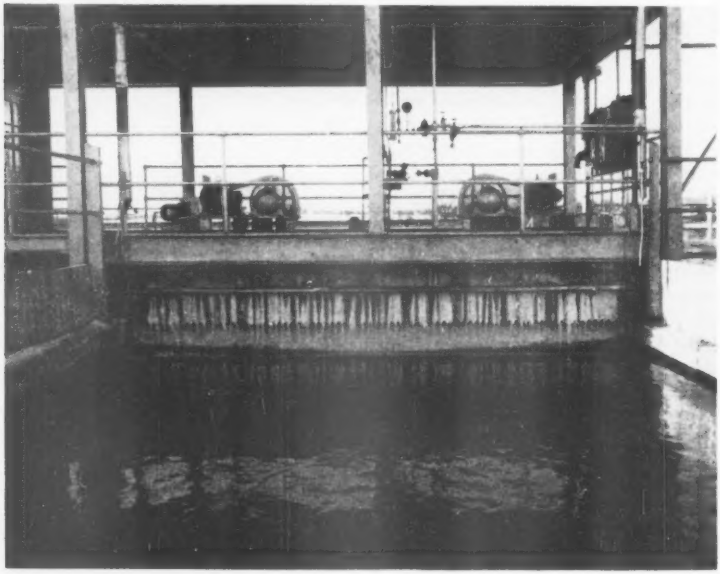

FIGURE 3.—Neutralizing equipment.

decomposition of the sludge retained in the settling basin, samples of sludge were collected for analysis. One sample, designated "A-fresh," consisted of recently deposited sludge, and another sample, designated "B-old," represented material which was accumulated over a period of 6 years, removed from the settling basin and stored for about 6 months in a dry basin.

Both sludges were produced from wastes which had, in general, the same characteristics. The odor of both sludges was distinctly "chemical" and similar to the odor of the waste.

Analyses were made on the samples for total solids, ash, organic matter, total nitrogen, free rhombic sulfur, and total bacteria (20° C. nutrient agar count). The percentage organic matter was determined by acidifying dried samples of sludge to cause evolution of carbon dioxide from carbonates and then igniting, and determining the loss of weight. No evidence of carbonates was noted on acidification.

The results of these analyses were as follows:

Sludge Sample	A—Fresh (%)	B—Old (%)	Actual Change on Basis of Original (%)
Total solids	20.2	34.4	+70.3
Organic matter	50.0	40.2	−19.8
Ash	50.0	55.8	—
Total nitrogen	0.175	0.033	−82.1
Free sulfur	3.29	3.69	+ 0.6
Bacteria per gram dry solids	5500	2700	—

Significant points shown by the analyses and additional laboratory engineering investigation are as follows:

Evidence that some form of decomposition occurs in the sludge is indicated by the reduction in organic matter. Since the Calco Bound Brook waste contains the domestic sewage of the employees, it may be assumed that if decomposition takes place, the organic matter of the sewage would be destroyed. The rather low percentage reduction in organic matter over a period of more than 6 years shows that the decomposition takes place very slowly and may be limited to the organic sewage solids. However, based upon the results obtained, it appears that gas evolution and the possibility of odor production is negligible.

To obtain some information in connection with odorous sulfur compounds which might be evolved during decomposition, the percentage of sulfur present and the actual amounts destroyed were determined. The figures show that relatively large amounts of sulfur are present in the freshly deposited sludge. However, the actual amount of sulfur reduction was practically nil, so that odors from this source cannot be expected.

Of some interest is the fact that rather small numbers of bacteria were found in the fresh and old sludges. Considering that an ordinary garden soil contains from 2 to 6 million bacteria per gram of dry material, the numbers of bacteria present in the sludges are very small. However, the presence of these organisms in low numbers also gives a clue that actual biochemical stabilization takes place, but at a very low rate.

Engineering studies carried out on a small scale showed that the sludge could not be dewatered by filtration, as the fine particles of sludge immediately blinded all filtering media investigated. Chemical treatment also failed to accomplish the desired dewatering. Only freezing was found to have a beneficial effect in concentrating the solids.

Since no means of treatment has been found, the sludge from the compositing and settling basins is being retained in two storage basins.

Aeration

No changes have been made in the means of aeration; the several hydraulic stairs which follow the settling lagoon still serve to aerate the effluent, but because the effluent is so inert to dissolved oxygen, the total apparent chemical oxygen-consuming power determined by permanganate is not reduced appreciably. This is further evidence of the very sluggish nature of the majority of the chemical oxygen-consumers that remain after passing through all the steps of the process. In cool weather, the effluent, having a "B.O.D." of, say 100 p.p.m., may at the same time have a dissolved oxygen content as high as 60 per cent of saturation. In warmer weather, the effluent will consume dissolved oxygen to a certain small extent. One effect of aeration is the removal of CO_2 from the effluent. When the effluent meets the river at the diffusion dam there is more aeration.

Diffusion and Dilution in the River

Adequate dilution of the effluent in the river has been denied at times. The plant has grown and the river has shrunk, both relatively and actually, and this means that efforts to improve waste treatment must be continued so as to be less affected by periods of smaller dilution. Flood control, if applied to the river, would help greatly in maintaining a more uniform dilution ratio throughout the year. The results so far achieved have been accomplished in spite of a 1944 drought as severe and more prolonged than that reported in 1941. In 1945 and 1946 a larger amount of rainfall gave better dilutions.

The diffusion dam suggested originally by the New Jersey State Department of Health serves to diffuse the effluent almost immediately into the whole river. The dam has been cleaned out only once in its 6 years of operation, and that was because during its construction not all the gravel was cleaned out of it. After removing the gravel, some ports near the intake side were throttled to effect more even distribution across the river. The diffusion dam is so constructed that it also draws in air with the effluent. This is very effective in putting dissolved oxygen into the river, especially during low water levels which occur in late summer. The aspirated air, however, helps also to create foam. In order to retain this helpful aeration and at the same time prevent any foam disfiguring the surface of the river, the foam seine shown in Figure 4 was constructed.

Foam Removal

The foam seine was made by attaching water-proof curtains on the downstream side of a pontoon bridge which is stretched across the river about 75 ft. below the diffusion dam. The bridge is made of ten pontoons and necessary connecting catwalk. The curtain is immersed about 6 in. in the river. The curtain material was originally canvas impregnated with a mold preventive. As this eventually rotted away at the surface of the water, planks were substituted for the parts in contact with the water, and no trouble has resulted since.

On several occasions large trees have been carried down the river during storms and have damaged the seine. For this reason a couple of extra pontoons are kept on hand so that quick repairs can be made. It has also been necessary to remove the foam seine during periods of high water.

The foam back of the seine has such small substance that it gradually wets out and disappears.

Present Status of Treatment

Efforts since 1942 have been devoted to meeting the last two of the requirements of the New Jersey State Department of Health, namely, complete re-

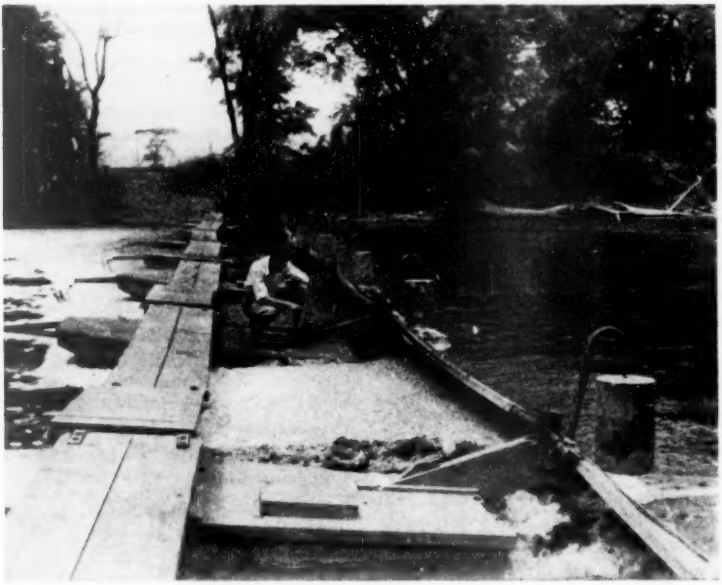

FIGURE 4.—Foam seine in Raritan River.

moval of foam and additional reduction of B.O.D. Handicapped and delayed because of the war, and even after the war by the inability to secure enough materials or manpower to put into effect the results of work that had been done, it has been possible finally to meet all but one of these requirements.

The requirements outlined 7 years ago by the New Jersey State Department of Health for Calco's effluent were as follows:

"1. The effluent shall contain no free acidity; that is all the titratable acidity shall be neutralized."

This has been interpreted as all the acidity below pH 4.0 to 4.2, which is the endpoint of erythrosine indicator. It has been demonstrated that further neutralization with $CaCO_3$ is impractical, as excessive quantities of $CaCO_3$ would be required, much of which would be wasted by not reacting. The greater the degree of neutralization, the higher the turbidity. Further neutralization does not substantially reduce oxygen-consuming power and changes the color of the effluent from a clear tea color to a slightly turbid yellow.

"2. The effluent shall be free of noticeable floating solids, oil, grease or sleek."

The appearance of the river was given special attention and the reach below the outfall has seldom had anything on it since the installation of the foam seine.

"3. The effluent shall be sufficiently free of color or turbidity, or both, so that after dispersion in the receiving waters, or not more than 1000 ft. above or below the point of effluent discharge, it will not noticeably discolor, or add to the turbidity of the receiving waters."

The color of the river is nearly normal all of the time. Most of the colors in the effluent are destroyed by the varied chemical reactions which occur during compositing. The treated efflu-

ent itself is uniformly a light tea or amber color. This tea color always dilutes out to no visible color with a dilution of river water of about 10 times the volume of the effluent. The effluent is never turbid and is always clearer than the river itself, measured turbidities being 2 to 3 p.p.m. It is not, therefore, adding to the turbidity of the river.

Periodic dye tests are made on river water every 3 months by making a test run on 5 consecutive days in one week on cotton, silk and wool to determine whether dyeing or staining materials are escaping.

"4. The effluent shall be free of caustic alkalinity or other toxic or deleterious substances."

The effluent is never caustic. No poisons, such as arsenic are employed in the plant, and materials which might be thought toxic are carefully removed at the source by systems of scrubbers, recovery, burial, chlorination or other special means of disposal.

"5. The effluent shall be free of offensive odors."

The Calco Chemical Division has an elaborate air pollution control system, and means have been provided for preventing odors in the effluent, one of the most important of which is the treatment at the source for sulfide brines. This installation destroys the sulfides, polysulfides, and sulfhydrate in mother liquors or filtrates so that hydrogen sulfide cannot be liberated later on. There are also recovery processes and traps for the removal of other odoriferous materials. A special pyridine recovery plant is in operation for the removal of pyridine from the effluent.

"6. The effluent shall be of such quality that organisms of the coli-aerogenes group shall be present in not more than 20% of the one (1) cubic centimeter portions examined from any one sample or any series of samples of the effluent tests. For the purpose of the test for organisms of the coli-aerogenes group, a sample shall consist of five 1-cm. portions."

The Calco effluent never contains organisms of the coli-aerogenes group. As the sanitary sewage is constantly in contact with acid wastes, the sewage is being acid treated from the moment it enters the system. During the time the various wastes are collected in the pumping station sump of 350,000 gal. capacity, and while they are composited in the compositing basin of 11.5 m.g. capacity, they are in contact with strong acids, and any organisms in the sanitary sewage are completely destroyed. Neutralization is maintained at pH 4.0, which guarantees complete destruction in the settling lagoon of any bacteria which might escape the higher acidity of the compositing basin.

"7. The effluent shall have a biochemical oxygen demand not exceeding in the average over any four (4) hour period of a day 100 p.p.m., and not exceeding at any time 125 p.p.m. The effluent after dispersion in the receiving waters, or not more than one thousand (1,000) feet above or below the point of effluent discharge, shall not reduce the dissolved oxygen content in such receiving waters below fifty percentum (50%) saturation.

In order to meet this requirement, all wastes of high chemical oxygen-consuming power and large volume were collected for special treatment. The sulfide brines were collected and a treatment plant was built to destroy them. Various other recovery plants removed other high oxygen-consumers, and improvements in sulfur dioxide recovery and other processes reduced the amount of oxygen-consuming material delivered to the treatment plant so that the reactions taking place in the compositing basin can carry the reduction of chemical oxygen-consuming power to the desired limits.

It is estimated that the completion of the treatment at the source of all sulfide brines will reduce the B.O.D. of the combined effluent by 23 p.p.m., and that the completion of the SO_2 re-

covery operations will effect a further reduction of 30 p.p.m.

General Conclusions

1. The Raritan River is very flashy, and because there is no flow control to maintain a more or less uniform flow of water, there are times when dilution is inadequate.

2. Natural reaeration of the river is insufficient to maintain dissolved oxygen during low-flow conditions.

3. Complete neutralization does not maintain as low a coliform bacteria count as the present practice of neutralizing to pH 4.0.

4. Settled sludge shows some slight digestion of organic matter and can be stored without odor.

5. Treatment at the source, especially of sulfur-containing wastes, results in effective removal of oxygen-consuming compounds and color.

6. A foam seine has been effective for capturing and retaining any foam produced at the outfall.

7. The effluent is uniformly distributed into the river flow to take full advantage of such dilutions as is available.

8. The suggestion is offered that industry could be helped in stream pollution control by the allocation of reasonable amounts of such properties as dissolved oxygen content and acid neutralizing power of the streams, based upon comprehensive studies of the streams themselves; also, that industry's efforts would be augmented and greatly aided if the appropriate authorities were to assume actively the obligation of providing adequate dilution by maintaining a reasonable uniform flow in stream. In many streams the water is wasted during periods of high runoff, with the result that periods of low water and inadequate dilution follow.

DISPOSAL OF CHEMICAL MANUFACTURING WASTES—A DISCUSSION

By R. D. Hoak

Senior Fellow, Mellon Institute of Industrial Research, Pittsburgh, Pa.

Dr. King prefaced his paper by stating that progress in pollution abatement is too slow, and suggests that it could be accelerated if regulatory authorities would permit industry to employ a reasonable fraction of the reserve of dissolved oxygen and alkalinity in streams to supplement industrial waste treatment.

This is a proposal that will be regarded as a kind of heresy by those who maintain that all pollutional matter should be reduced to the lowest practical limit before discharge. Whether one agrees with Dr. King that streams should be required to carry part of the burden of waste treatment depends upon the point of view. If the problem is examined in the light of the best public interest, there is no question but that there must be a qualified concurrence in his recommendation. Most streams have a considerable capacity for assimilation of various kinds of pollution without adverse effect on downstream riparian interests. Where this capacity is not properly utilized, it represents an economic waste that will inevitably be reflected in higher costs for manufactured products, because of an increasing acceptance of the principle of regarding the cost of waste treatment as a part of the cost of production.

There is no intention of suggesting that streams be loaded to capacity, or that they be asked to perform functions of which they are incapable. Intelligent application of the doctrine of reasonable use would provide a sound

control of stream quality. Public health engineers may admit the merit in proper use of some fraction of stream capacity for waste treatment, but they are likely to claim that the administration of such a principle would be impractical.

Proper control of waste treatment, where a reasonable proportion of stream capacity is used as a supplementary treatment, need be no more difficult than current practice, when limiting standards have been set. A requirement that operation reports include analysis of samples above and below the point of discharge would provide assurance that an effluent was not taxing a stream beyond the proportion of its capacity that had been allocated to a particular mill.

It happens all too often that the requirements of state authorities are so stringent that an industry frequently finds it so difficult and expensive to meet unreasonably strict standards that progress in pollution abatement is retarded. The widespread public interest in pollution abatement is a persuasive indication that there will be continued pressure for cleaner and cleaner streams. Satisfactory treatment of industrial waste water is generally a complex and costly problem; in many cases the degree of treatment specified for a particular waste cannot be met by known means, or waste processing costs may be prohibitively high. In view of the strong likelihood that streams which are considered to be in satisfactory condition today will be regarded as unnecessarily polluted at some time in the future, it would seem to be preferable to settle now for a somewhat lower degree of waste treatment than local conditions would appear to demand. With the establishment of partial treatment at a plant, successive improvements would usually be less difficult to obtain than an initial installation that would provide the most complete treatment possible. Such a progressive plan would have the virtue of allowing for unforseen, but basic, process changes, through the inclusion of a degree of flexibility of design impossible in a treatment plant constructed to accomplish a particular immediate result. In addition, provision of partial treatment would permit more accurate estimates of eventual requirements than would be possible where standards were set arbitrarily.

This approach to waste treatment may not appeal to industry in general. Few companies will undertake waste treatment voluntarily, not only because of the expense, but because operation of the necessary plant adds just one more distraction to the multiplicity of problems a manufacturing plant faces today. When the average manufacturer agrees to the installation of waste treatment works, his normal reaction will be to insist that the plant decided upon shall protect him from further harassment for a fairly definite number of years. This is an understandable attitude, but it is not necessarily a sound one. The layman thinks that industry often wilfully despoils streams because it refuses to bother about recovering the "valuable" materials discharged in waste water. It is perhaps unfortunate that so much publicity has been given to a few cases of really important savings from recovery of products once considered as unavoidable manufacturing waste. The fact is that the obviously recoverable materials are being reclaimed in the great majority of instances, through pressure to reduce costs to meet competition. The principal source of savings in improving the quality of waste water discharges lies in preventing process material from finding its way into plant sewers. Periodic waste water surveys will prove to be profitable by preventing wastage and by reducing the load on treatment plant or stream. The proposal for accomplishing pollution abatement by successive improvement of treatment practice would serve the

dual purpose of meeting its primary objective while forcing a regular examination of manufacturing operations to reduce waste at its source; and the savings disclosed by the latter will frequently contribute substantially to reducing the cost of the former.

The data that Dr. King and his staff have presented lend support to the thesis that the Raritan River has sufficient resources of dissolved oxygen and alkalinity to provide a modest supplementary treatment for the Calco effluent. The data on dissolved oxygen and B.O.D., taken together, reveal an interesting situation. Despite the fact that effluents from three sewage plants and four chemical factories reach the river between the Calco plant and Landing Bridge, the D.O. was less than 4 p.p.m. on only two of the five dates for which figures are given for Landing Bridge, and these occurred when the tide was out. When the tide was in, the dilution it afforded raised the D.O. to 6.8 p.p.m.

The B.O.D. data illustrate the frequently encountered toxic effect of industrial wastes on biological flora. The lower the dilution of the waste, the more pronounced is the lag in development of biological activity. The stream flow data show that the flashy Raritan River occasionally provides a dilution ratio less than 10:1. But it will be observed that the average time of passage of the Calco effluent to Raritan Bay is only a little more than 24 hours, and rapid biological activity does not begin at low dilution until at least the second day. The high D.O. at Landing Bridge shows that not only Raritan Bay, but also the tidewater some 11 miles from the bay, has a large capacity for assimilating oxygen-consuming matter. This indicates that the oxygen demand of the Calco effluent should not place a serious burden on the stream, even at low dilution, between the plant outfall and tidewater.

A similar argument can be sustained on the demand of the Calco effluent for stream alkalinity. Dr. King has shown that use of only 5 per cent of the average stream alkalinity at the Calco outfall would save about 1148 tons of carbonate per year. It would seem that this would be a moderate demand to place on the stream. It is important to recognize, however, that in any allocation of stream resources to industry the allocation must be made on a basis of stream condition at the site of that plant. Obviously, if each of 20 plants was assigned 5 per cent of a stream's resources measured at some arbitrary upstream point, the last consumer would reduce those resources to zero, and such a situation would convert the argument for allocation to an absurdity.

These comments have dealt with broad generalizations, and it is recognized fully that circumstances vary widely. An attempt has been made only to elaborate somewhat on the doctrine of reasonable use of streams. In most instances, industrial waste engineers and the personnel of state health departments have placed their major emphasis on effluent quality rather than on the stream itself. In certain respects this is a misplaced emphasis. The problem is to restore streams to a satisfactory condition and to prevent destruction of streams now undefiled. It would seem to be only logical to use the stream as a criterion of what may be discharged to it. Intensive stream study will be necessary to evaluate the contribution to the national economy that can be expected from this source. There is no intention here to suggest that industry be given a free hand to discharge untreated effluents and then justify their action by attempting to prove that the stream has adequate resources to assimilate the wastes. What is intended is to call attention to the economic waste that occurs when an unneces-

sarily elaborate treatment plant is installed as a safety factor against inadequate knowledge of stream ecology. Pollution abatement involves difficult problems of technology and economics, but they can be solved by intelligent cooperation between industry and public agencies. There are many sincere conservationists in industrial management, but their wishes are often limited by economic factors beyond their control.

Dr. King and Calco are to be commended for their studies. It is hoped that additional data will be collected, particularly for both high and low tides at Landing Bridge, over a sufficiently long period to provide a thorough evaluation of the factors described in this paper.

U. S. PUBLIC HEALTH SERVICE ENGINEERING ACTIVITIES REORGANIZED

Reorganization of the engineering activities of the U. S. Public Health Service as a result of enactment by the 80th Congress of Public Law 845 was announced recently by Surgeon General Leonard A. Scheele. The former Sanitary Engineering Division has been replaced by a Division of Sanitation and a Division of Water Pollution Control. Both of these divisions will be under the supervision of Assistant Surgeon General Mark D. Hollis, Chief Sanitary Engineering Officer.

Also announced were the appointments of M. Allen Pond as Assistant Chief of Engineering Activities; Carl E. Schwob as Chief, Division of Water Pollution Control; and Callis H. Atkins as Chief, Division of Sanitation.

Already functioning are four of the 14 proposed river basin offices being established to coordinate the Federal water pollution control activities with state, interstate, and local agencies—the Pacific Northwest Drainage Basin office at Portland, Ore., headed by Robert Harris; the Missouri River Basin office at Kansas City, Mo., headed by Glen Hopkins; the Great Lakes Drainage Basin office at Chicago, Ill., headed by S. C. Martin; and the New England Drainage Basin office at Boston, Mass., headed by L. W. Trager.

On February 12, President Truman appointed Thomas A. Berrigan, Chairman of the Merrimack Valley Joint Sewerage Board, Boston, Mass.; L. A. Danse, Chairman of the General Motors Industrial Waste Committee, Detroit, Mich.; Dr. Stanley B. Freeborn, Assistant Dean, College of Agriculture, University of California, Los Angeles; Michael Klein, Chief Engineer, Manhattan Borough President's Office, New York City; Carl D. Shoemaker, Conservation Director, National Wildlife Federation, Washington D. C.; and N. T. Veatch, Consulting Engineer, Kansas City, Mo., as the six nongovernmental members of the Water Pollution Control Advisory Board.

The Federal members of the Board, in addition to Assistant Surgeon General Hollis, who will serve as Chairman of the Board, are: Lt. Col. Hugh M. Arnold, Army Corps of Engineers; Milton C. James, Assistant Director, Fish and Wildlife Service; James W. Follin, Assistant Administrator, Federal Works Agency; and Ralph R Will, Administrative Officer, Department of Agriculture.

THE OPERATOR'S CORNER

UNDER NEW MANAGEMENT

Beginning with the next issue, *The Operator's Corner* will be compiled and conducted by Herbert P. Orland, formerly of New York City.

Mr. Orland will take the place of S. C. Martin, who left the Federation staff at the end of January to take a position as "Basin Engineer" in the organization that is being created in the USPHS to administer the new Federal pollution law. Martin has been assigned to the Great Lakes area, with headquarters in Chicago.

A civil engineering graduate of Cornell University, Mr. Orland is particularly well qualified for service as Assistant Editor of THIS JOURNAL by virtue of his 5 years experience with *Engineering News-Record* and in the technical publications office of the American Society of Civil Engineers. He has also had considerable experience in municipal management, including supervision over sewage works functions.

As has been pointed out many times in the past, this department of the JOURNAL requires broad and continuous participation on the part of plant superintendents and operators in order to fulfill its purpose. The ideal *Corner*, as we see it, would be made up of short practical contributions—by operators—describing their methods of overcoming day-to-day problems. It would include at least three or four descriptions of "gadgets"—those clever, home-made, labor-saving devices that are found in almost every sewage treatment plant but which are rarely publicized. It would contain references to experiences and operation reports from which a lesson is to be learned or a pitfall to be avoided. It would be what its name implies—a market place for operation personnel in plants of all sizes to exchange their trials, tribulations and troubles for solutions, solace and salvation!

Although our facilities are limited, we will cooperate in every way possible to prepare worth-while material for publication. Any reasonable rewriting, editing, preparation of drawings, etc., will gladly be undertaken. Letters and newspaper clippings are just as welcome as formal manuscripts.

Hundreds of the kind of items we are seeking lie buried today in the diaries, files and minds of plant operators everywhere. If resurrected, dusted off and passed along to us, we would welcome the opportunity to present them in the *Corner* for reference and use by our growing readership. And be sure to keep us in mind when you have contributions in the future.

Herb Orland is at your service. Just "pass the ammunition" and he will subject your problems to a barrage of practical answers. The *Corner* is under new management, but its aims are unchanged and its value, as in the past, depends upon your participation.

W. H. W.

THE OPERATION OF THE BACK RIVER SEWAGE WORKS, BALTIMORE, MD.

By C. E. Keefer

Deputy Sewerage Engineer, Bureau of Sewers, Baltimore, Md.

A new stage in the operation of the Back River sewage works, which serves the major portion of Baltimore City and a large part of the Baltimore County Metropolitan District, began on March 28, 1935. On that date the old manually-cleaned bar screens and primary settling tanks were superseded by mechanically-cleaned screens and tanks. At the same time two heated sludge digesters were put in operation. These changes eliminated the production of foul-smelling scum on the settling tanks and made it possible to apply a fresher effluent to the trickling filters. The rapid removal of the primary sludge to the heated digesters produced a material with a much higher pH value that could be digested in 30 days or less. These improvements were soon followed by others, consisting of grit chambers, additional primary settling tanks, activated sludge units, chlorinating equipment, additional heated digesters and vacuum filters. The cost of the treatment facilities constructed from 1930 to 1947 amounted to $3,859,500.

Description of Sewage Plant

The sewage plant (Figure 1) is situated on a 547-acre tract of land, approximately 2 miles east of Baltimore City. The sewage flows to the plant through a horseshoe-shaped concrete conduit, 12 ft. 3 in. wide by 11 ft. high, with a maximum capacity of 291 m.g.d. A flow diagram of the plant is shown in Figure 2.

Mechanically-Cleaned Screens

The raw sewage enters a brick building that contains three Link-Belt mechanically-cleaned screens, each with a rated capacity of 100 m.g.d. Each screen has ¾-in. clear openings between the bars, is 10 ft. wide, with a working depth varying from approximately 8 to 11 feet. In the rear of each screen there is a motor-operated Jeffrey grinder for shredding the screenings and returning them to the sewage.

Grit Chambers

From the screens the sewage flows to three mechanically-cleaned grit chambers, each 50 ft. square, with a working depth varying from 3 ft. 9 in. to 6 ft. 3 in., depending upon the rate of sewage flow. Each grit chamber, which is equipped with a Dorr detritor, is designed to treat a flow of 100 m.g.d. The grit discharges from the detritor on a horizontal belt and is conveyed to a nearby building where a vertical elevator loads it into trucks.

Preliminary Settling Tanks

After leaving the grit chambers the sewage flows through five 54- by 30-in. Venturi meter tubes to five preliminary settling tanks. Each tank, which is equipped with a Dorr rotary-type sludge removal mechanism, is designed to treat 25 m.g.d. with a theoretical detention period of 2 hours. Two of the tanks are 140 ft. square with a side-water depth of 13 ft., and the other three are 170 ft. in diameter with a side-water depth of 10 feet 6 inches.

Drum-Type Fine Screens

The sewage flows from the settling tanks to five motor-driven drum-type revolving screens. Each screen, the framework of which is made of white oak, is 10 ft. long and 12 ft. in diameter. The screens are covered with 20-mesh, 0.015 in. monel wire cloth

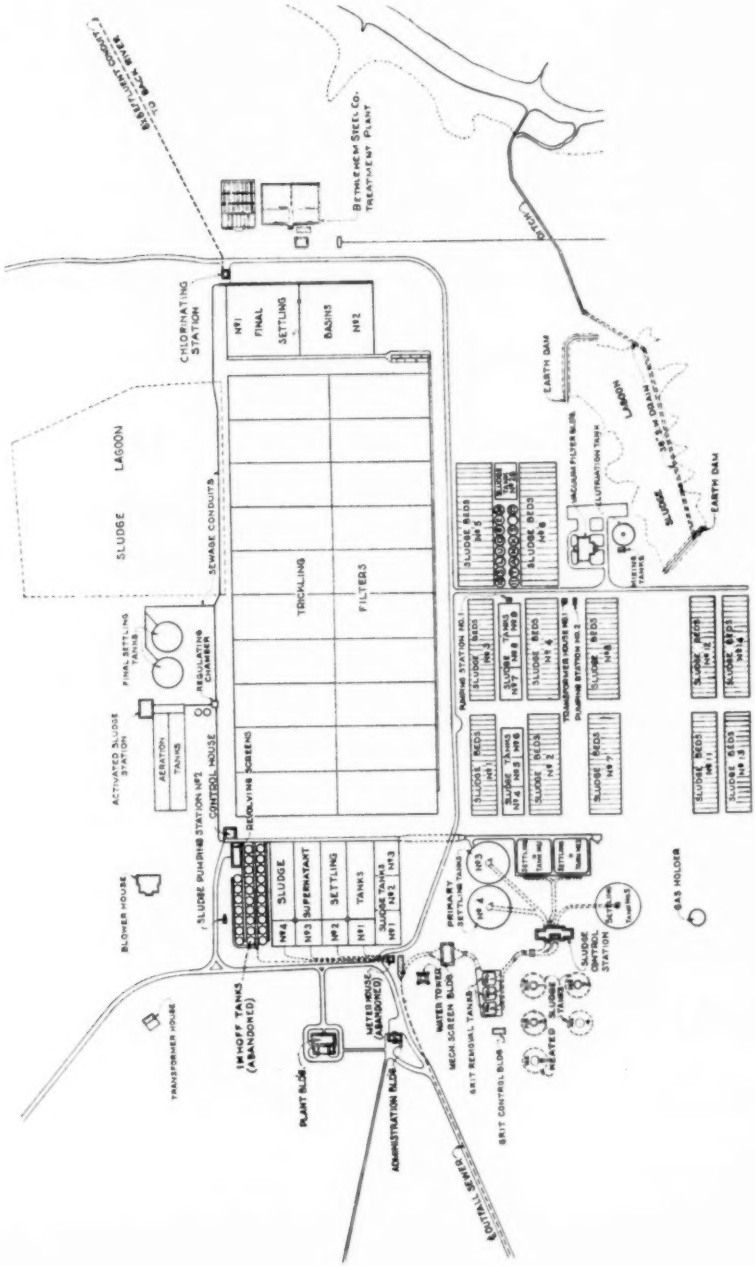

FIGURE 1.—Back River Sewage Works.

and operate at speeds varying from 52 to 59 seconds per revolution. The sewage enters one end of the drum, which is open, and flows radially outward through the screen. As the screen rotates, the screenings adhere to the inside of the cloth and are lifted out of the sewage. Water from a spray pipe, which is suspended in a horizontal position immediately above the screen, impinges on the outside of the screen cloth and washes the screenings into a trough. This trough hangs inside the screen above the sewage. The screenings and wash water flow to three circular Imhoff tanks for treatment.

Trickling Filters

The effluent from the screens divides into two parts; the major portion flows to trickling filters and the remainder is treated in activated sludge units. The trickling filters, which cover 30 acres, are 1758 ft. long, 800 ft. wide, and 8½ ft. deep. The filters are divided into 10 beds, each of which is served by a separate conduit. In each conduit there is a butterfly valve that makes one rotation in about 4 minutes and regulates the flow to the beds. The filter media consists of trap rock, 1 to 2½ in. in size. There are 5830 nozzles on the beds, spaced 15 ft. apart. Three kinds of nozzles are used: Merritt square spray, Worcester, and Columbus.

Humus Tanks

Following the trickling filters there are two manually-cleaned humus tanks, each 277 by 290 ft. in plan, with a side-water depth of 9.5 feet. Between these tanks there is a small pumping station that contains a vertical centrifugal pump for handling sludge and supernatant.

Activated Sludge Units

A 7-ft. square conduit with a maximum capacity of 210 m.g.d. conveys the effluent from the fine screens to the aeration tanks of the activated sludge plant, which is designed to treat an average flow of 20 m.g.d. and a maximum flow of 40 m.g.d. There are two two-pass aeration tanks. Each flow through channel is 383 ft. 3 in. long, 30 ft. 3 in. wide, with a water depth of 15.29 feet. From the aeration tanks the mixed liquor flows to two circular sedimentation tanks, each 126 ft. in diameter with a side-water depth of 13 feet 4 inches. These tanks are provided with rotary sludge removal equipment.

The excess sludge discharges into two Dorr thickening tanks, each 26 ft. in diam., with a working depth of 16 ft. at the tank wall. The thickened sludge flows by gravity to two plunger pumps, each with a rated capacity of 140 g.p.m. The sludge can be pumped into the raw sewage or into the digestion tanks. Chlorine is applied to the supernatant liquor in the thickening tanks and can also be added to the activated sludge that is pumped into the aeration tanks to control bulking.

Adjacent to the aeration tanks a building houses three 16,500-cu. ft. per min. centrifugal blowers. This building also contains primary and secondary air filters through which the air passes to the blowers.

The effluent from the final settling tanks following the aeration tanks flows to sewage treatment facilities owned and operated by the Bethlehem Steel Company at the Back River sewage works. The effluent is used by this company for industrial purposes.

Chlorinating Equipment

Since 1945 the effluent has been chlorinated each year from the middle of April to the middle of September in order to reduce the bacterial load in the river. Three rotometers are used to apply the chlorine to the sewage. Each meter has a capacity of 6500 lb. per day when the gas pressure is 9 lb. per sq. in. and the temperature is 70° F.

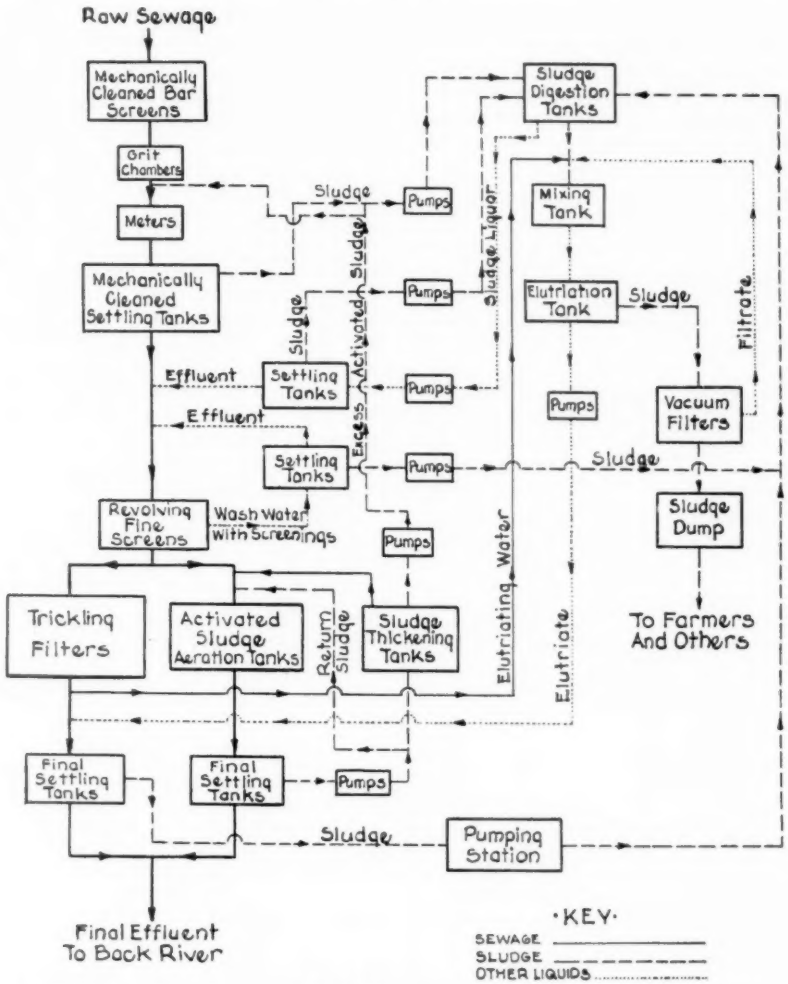

FIGURE 2.—Flow diagram of Back River Sewage Works, Baltimore, Md. (1945).

Sludge Digestion Tanks

As of December 31, 1947, there were 13 sludge digestion tanks in operation with a working capacity of 2,326,100 cubic feet. Three of these, which are heated and provided with covers for gas collection, have a working capacity of 554,700 cu. ft., and the remaining ten are unheated open tanks with a working capacity of 1,771,400 cubic feet.

Sludge Filtration

The digested sludge is elutriated with trickling filter effluent and dewatered on vacuum filters. From November 11, 1938 to April 30, 1946, two filters with a surface area of 1000 sq.

ft. were in operation. Since the latter date two additional filters of the same size as the original filters have been in service. The sludge is coagulated with chlorinated copperas, which is made at the sewage works by adding chlorine gas to ferrous sulfate.

Sludge Cake Disposal

The dewatered sludge is deposited in a pile adjacent to the building containing the vacuum filters. From here the cake is loaded into trucks by a 5-ton locomotive crane and dumped on the grounds of the sewage plant. From time to time small quantities have been hauled away and used for fertilizer purposes.

Operating Procedure and Results

Raw Sewage Characteristics

The sewage flows to the treatment works in a separate system of sewers. That some storm water gets into the sewers is evidenced by the increased flow during rainy periods. As some of the sewage flows for 15 to 20 miles before reaching the sewage plant, it is stale when it arrives there. The raw sewage is considerably stronger than normal domestic sewage. The average 5-day B.O.D. has varied from 202 to 302 p.p.m. (Table I) and from 0.21 to 0.28 lb. per capita per day during the 8-year period from 1940 to 1947, inclusive. During this same time the average yearly suspended solids have

TABLE I.—Analyses of Raw and Treated Sewage [1]

Year	Raw Sewage			Primary Effluent		
	5-day B.O.D. (p.p.m.)	Solids		5-day B.O.D. (p.p.m.)	Solids	
		Susp. (p.p.m.)	Settl. (p.p.m.)		Susp. (p.p.m.)	Settl. (p.p.m.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1940	266	151	100	184	64	30
1941	250	162	118	186	84	39
1942	287	226	170	207	85	37
1943	288	257	191	216	97	48
1944	302	274	196	238	100	50
1945	248	227	161	213	92	48
1946	220	172	129	147	67	32
1947	202	194	138	160	74	39

Year	Trickling Filter Effluent				Final Effluent			
	5-day B.O.D. (p.p.m.)	Solids		Nitrates (p.p.m.)	5-day B.O.D. (p.p.m.)	Solids		Nitrates (p.p.m.)
		Susp. (p.p.m.)	Settl. (p.p.m.)			Susp. (p.p.m.)	Settl. (p.p.m.)	
	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1940	46	45	28	7.7	49	55	34	7.5
1941	39	36	26	12.6	43	42	25	11.6
1942	45	45	28	14.1	51	46	29	11.3
1943	—	—	—	—	—	—	—	—
1944	—	—	—	—	—	—	—	—
1945	—	—	—	—	—	—	—	—
1946	—	—	—	—	—	—	—	—
1947	—	—	—	—	—	—	—	—

[1] See Table VI for the analyses of activated sludge plant effluent.

ranged from 151 to 274 p.p.m., or from 0.14 to 0.26 lb. per capita per day. There was a continued increase in the strength of the sewage from 1940 to 1944, and a decrease since then. No one industry is responsible for the sewage being stronger than normal. Baltimore has a number of diversified industries such as canneries, slaughter houses, breweries, dairies and laundries, the wastes from which augment the organic load in the sewage.

Sewage Flow

There has been an increase in the flow of sewage (Table II) from 88.30 m.g.d. in 1940 to 118.52 m.g.d. in 1947, amounting to about 34 per cent. The estimated number of persons served increased from 806,900 to 941,700 in this 8-year period, and the average sewage flow per capita has varied from 102 to 126 gal. per day. The per capita flow has been increasing during the past 3 or 4 years, perhaps due in part to the augmented industrial activity during and following the war. The hourly variation in the sewage flow for 1947 is shown in Figure 3. The maximum flow usually occurs at 3 P.M., because several hours are required for the flow to reach the treatment plant.

TABLE II.—Population Served and Sewage Flow

Year	Population Served	Sewage Flow	
		Total (m.g.d.)	Per Capita (g.p.d.)
1940	806,900	88.30	109
1941	821,100	89.41	109
1942	922,200	93.75	102
1943	930,200	99.98	108
1944	932,800	104.80	112
1945	930,500	108.11	116
1946	931,700	113.03	121
1947	941,700	118.52	126

Figure 4 indicates the frequency with which high sewage flows have occurred. Peak flows two or more times greater than the average can be expected for approximately 0.5 per cent of the time, with flows of two and one-half or more times greater than the average for 0.05 per cent of the time.

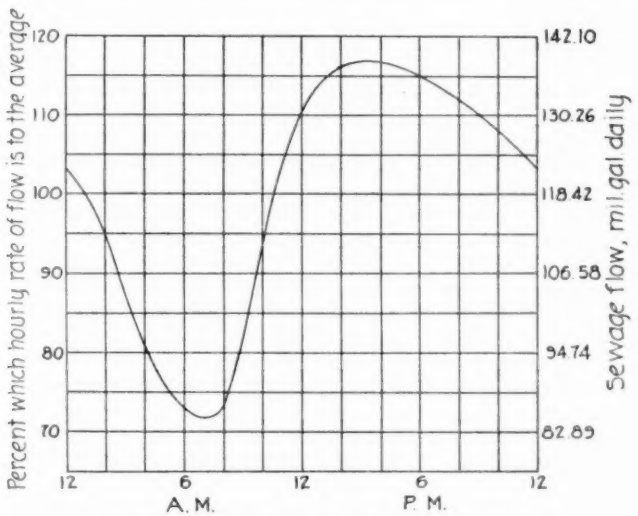

FIGURE 3.—Hourly variation in sewage flow for 1947.

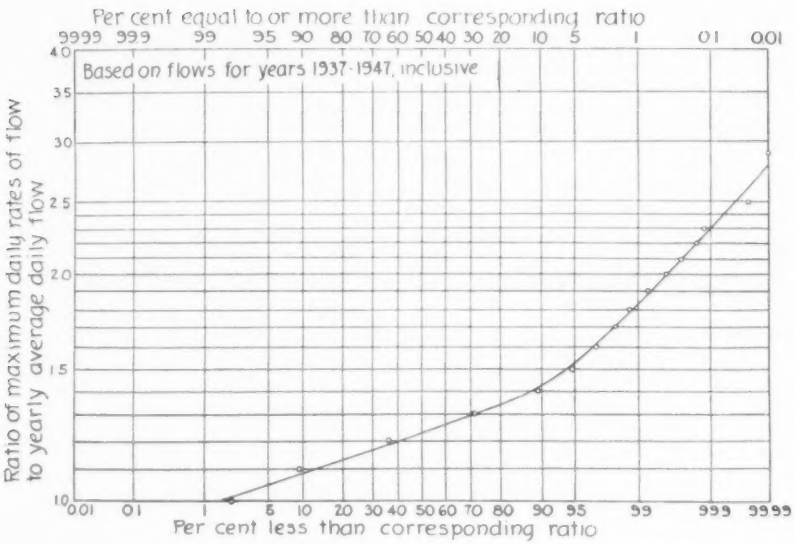
Per cent equal to or more than corresponding ratio
9999 999 99 95 90 80 70 60 50 40 30 20 10 5 1 01 001
Based on flows for years 1937-1947, inclusive
Ratio of maximum daily rates of flow to yearly average daily flow
4.0
3.5
3.0
2.5
2.0
1.5
1.0
001 01 1 5 10 20 30 40 50 60 70 80 90 95 99 999 9999
Per cent less than corresponding ratio

FIGURE 4.—Frequency of ratios of maximum daily rates of sewage flow to yearly average daily flow.

Mechanically-Cleaned Screens

Two of the mechanically-cleaned screens have been in service since March 28, 1935, and the third since April 13, 1937. On the whole they have presented few operating difficulties. To obtain proper operation it is essential to prevent the accumulation of sewage solids in front of and at the base of the screens, otherwise the cleaning rake cannot reach the bottom of the screen and will become inoperative. The first two screens were each provided with a screenings grinder. These machines were driven by 25-hp., 1140-r.p.m. motors. Operating experience indicated that better results would have been obtained by using larger motors running at higher speeds. The third screen, therefore, was equipped with a 30-hp. motor running at 1740 r.p.m. Experience with screenings grinders of various sizes at other locations in Baltimore indicates that a speed of 2100 r.p.m. gives even better results. Babbitted bearings were originally provided in the 1740-r.p.m. grinder. These bearings were unsatisfactory and were replaced with ball bearings, which have given good service.

In the original installation the material from each screen discharged into a vertical sheet metal hopper, the bottom of which connected with the top of the grinder. This hopper had an opening 9 ft. 11⅝ in. by 8 in. at the top and 1 ft. 5¼ in. by 8 in. at the bottom. It was soon observed that the screenings could not be discharged directly into the grinder, as it would become overloaded and would stall. To correct this condition a gently sloping plywood shelf was installed in the top of the hopper. The screenings discharge on this shelf and are gradually washed into the grinder by a stream of water. When the third screen and grinder unit was installed, a motor-driven horizontal belt conveyor was provided in the top of the hopper. The screenings discharge on this con-

veyor and are slowly fed into the grinder.

Each of the steel cables that are attached to each end of the rake and raise and lower it passes through a small hole in a stationary wiping block and is wound on a revolving drum. The wiping blocks remove any debris hanging on the cables. Blocks of various materials such as wood, rubber, and lead were tried, but were unsuitable. Blocks of compressed linen, however, have given good service.

When the building housing the screens was constructed, no provision was made to heat the screen room. Experience soon indicated the desirability of providing heat. As a considerable surface of sewage is exposed to the atmosphere, the air at times becomes laden with moisture, and exposed metal surfaces corrode quickly. The installation of unit gas heaters has helped to correct this condition. The electrical equipment on the switchboard in the screen building was cadmium plated when it was installed. This plating was soon attacked by hydrogen sulfide in the atmosphere and converted to cadmium sulfide.

Grit Chambers

Table III gives the amount of grit removed by the grit chambers. The quantity has varied from 2.1 to 4.4 cu. ft. per m.g of sewage and has averaged 2.6 cu. ft. per m.g. of sewage during the 5-year period from 1940 to 1944, inclusive, and 4.2 cu. ft. during the 3-year period from 1945 to 1947, inclusive, an increase of 61.6 per cent. The sewage flow was 21 per cent greater during the latter period. As there was considerable grit deposited in the outfall sewer leading to the treatment plant, this increased flow has resulted in greater velocities in the sewer, which, it is believed, have carried more grit to the sewage plant.

TABLE III.—Quantity of Grit Removed

Year	Grit Removed (cu. ft./m.g.)	Per Cent Volatile Matter (dry basis)
1940	2.9	—
1941	2.5	—
1942	2.9	43.6
1943	2.1	37.0
1944	2.5	40.2
1945	4.4	74.6
1946	4.4	61.3
1947	3.7	60.0

The volatile matter in the grit is quite high and has varied from a yearly average of 37.0 to 74.6 per cent on the dry solids basis. The grit is loaded into trucks at the grit chambers and deposited in dumps at the sewage plant. As this method of disposal is unsatisfactory, consideration is being given to incinerating the material.

The inlet and the outlet conduit to each grit chamber is provided with an 84- by 84-in. motor-operated steel sluice gate for controlling the sewage flow. Exposed limit switches, actuated by the gate, control the motor that operates the gate. In wet, freezing weather these switches were unsatisfactory. Where the operating spindle entered the switch housing, water collected and froze in cold weather, and the switches failed to operate. This difficulty is corrected by periodically applying a thick coating of heavy grease to the spindles.

TABLE IV.—Raw Sludge Production [1]

Year	Quantity Received			Solids Content (%)	Per Cent Volatile Solids (dry basis)
	Gal. per M.G. Sewage	Dry Solids			
		Tons Daily	Tons per M.G.		
1940	4780	70.1	0.80	3.9	81.2
1941	4930	67.4	0.75	3.6	79.2
1942	5370	74.9	0.80	3.5	81.9
1943	5170	76.9	0.77	3.5	84.1
1944	5000	84.8	0.81	3.8	83.5
1945	4780	72.4	0.67	3.3	82.0
1946	4670	66.6	0.59	3.0	79.6
1947	4150	77.3	0.65	3.7	78.3

[1] Includes waste activated sludge.

Primary Settling Tanks

Analyses of the sewage entering and leaving the primary settling tanks are given in Table I. The 5-day B.O.D. removal during the 8-year period from 1940 to 1947, inclusive, has averaged 23.5 per cent, and the suspended solids reduction has amounted to 59.6 per cent. The suspended solids content of the effluent has varied from 64 to 100 p.pm.

The yearly average raw sludge production (Table IV) varied from 4150 to 5370 gal. per m.g. of sewage. This sludge consists of primary settling tank solids, to which excess activated sludge has been added. The solids content of the raw sludge is quite low, for which condition there are two reasons. One is the presence of activated sludge, and the other is the method followed in withdrawing sludge from the primary settling tanks. Extending from the bottom of each tank there is an 8-in. cast iron pipe that terminates in an open sludge well. These pipes vary in length from 333 to 434 feet. The sewage in the settling tanks is 7 to 9.5 ft. higher than the pipe outlets in the sludge well. The hydraulic gradient along the sludge pipe is not sufficiently steep to permit the discharge of a concentrated material into the sludge well.

When the two square tanks were put in service the suspended solids content of the effluent was quite high. This condition was corrected by installing a wooden baffle (Figure 5) adjacent to the effluent weirs of the tanks.

Considerable maintenance has been required from time to time to keep the mechanical equipment in these tanks in service. The outer end of each

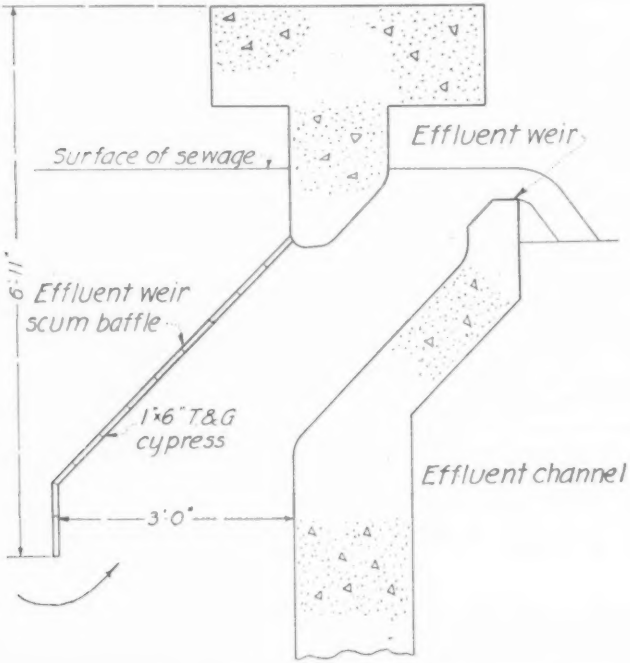

FIGURE 5.—Effluent weir scum baffle in primary settling tanks.

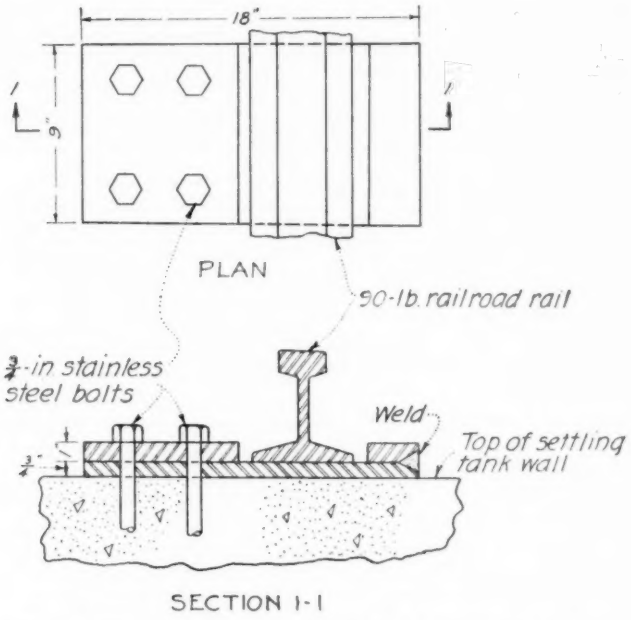

FIGURE 6.—Plate for holding railroad rails to settling tank walls.

bridge, from which the sludge squeegee equipment is suspended, runs on a 90-lb. railroad rail. This rail is secured to the tops of the tank walls by ¾-in. steel bolts. The horizontal thrust at the corners of the tanks was sufficient to shear off a number of these bolts. To correct this condition the rail was fastened to the wall by installing several specially made steel plates (Figure 6) which were secured to the top of the tank walls by ¾-in. stainless steel bolts.

At the center of each tank the sludge removal mechanism moves in and out on four steel rollers. Each pair of rollers supports a steel plate 6 in. wide and ¾ in. thick. As these plates support the mechanism at the center of the tank, excessive stresses were produced in them, resulting in their splitting. They have been replaced with new plates with a Brinell hardness of 300 and so far have proved satisfactory.

Trouble developed in the bearings on the shafts, at the outer ends of the mechanisms, which support the main drive wheels. The babbitted bearings were replaced by bronze bearings, and the design was changed so that they could be lubricated more readily.

From the five settling tanks there is an 8-in. cast iron pipe laid on a grade varying from 0.3 to 0.4 per cent, through which scum flows to a sludge well. This pipe frequently becomes clogged with grease, especially in winter. To date no easy way of keeping it clean has been devised other than by cleaning it manually with the usual sewer cleaning tools. It is planned to install a large submerged gas burner in the manhole at the upper end of this pipe line and heat the scum as it enters the pipe. It is hoped that this pipe will then become clogged less frequently.

Revolving Screens

The function of the revolving screens is to remove any suspended matter from the settled sewage that may clog the spray nozzles on the trickling filters. These screens are invaluable, as they greatly reduce the number of men needed to clean the trickling filter nozzles. Careful supervision of the operation of the screens is necessary to keep the loss of head through them 1 foot, or less. Excessive heads cause the sewage to break through and damage the screen cloth. This cloth under normal operating conditions has a life of about 1 year.

Trickling Filters

Table V gives the loading on the trickling filters and the 5-day B.O.D. removal. The 5-day B.O.D. loading has varied from 421 to 677 lb. per acre-foot daily. The removal of B.O.D. has ranged from 73.1 to 79.0 per cent. Under these loadings the filters have been free from clogging. The 5-day B.O.D. of the effluent for the 4-year period from 1939 to 1942, inclusive, averaged 44 p.p.m. The nitrates averaged 11.5 p.p.m. during this same period. The number of trickling filter nozzles cleaned, based on yearly averages, has varied from 2.6 to 3.6 per m.g. of sewage treated, and from 7.1 to 9.1 per acre daily. As a rule two men, working 8 hr. per day, 6 days a week, are employed to clean the nozzles.

The beds were originally provided with Worcester and Merritt square-spray nozzles. As these wear out, they are being replaced with Columbus nozzles, which distribute the sewage on the filter stone more uniformly. Since 1935, 2900 Columbus nozzles have been installed on the beds.

The first 12 acres of the filters that were constructed were provided with 6-in. terra cotta distribution pipes encased in concrete. These pipes are still in excellent condition after 36 years of service. The distribution pipes in the remaining 18 acres are cast iron. When they were examined in 1940, they were coated on the inside with a layer of slime and rust about 1 in. thick. As the volume of sewage passing through the pipes was considerably reduced by the slime layer, distribution of sewage on the beds was poor. These pipes were cleaned in the following manner. A portable gasoline-driven pump, capable of delivering 22 g.p.m. at a pressure of

TABLE V.—Loading on Trickling Filters

Year	Sewage Flow (m.g.d.)	Population Served	Filter Loading						B.O.D. Effluent (p.p.m.)	B.O.D. Removal		
			Per Acre (m.g.d.)	Per Acre-Foot (m.g.d.)	Persons Per Acre-Foot	5-Day B.O.D.				Per Acre-Foot (lb. per 24 hr.)	Per 1000 Cu. Ft. (lb. per 24 hr.)	Per Cent
						Influent (p.p.m.)	Per Acre-Foot (lb. per 24 hr.)	Per 1000 Cu. Ft. (lb. per 24 hr.)				
1937	77.71	695,000	2.59	0.305	2720	166	421	9.68	39	322	7.41	76.5
1938	76.06	735,000	2.54	0.301	2880	177	440	10.11	38	346	7.96	78.5
1939	78.41	713,000	2.61	0.307	2800	175	448	10.30	47	328	7.55	73.1
1940	71.49	653,000	2.38	0.280	2560	184	430	9.87	46	322	7.41	74.9
1941	75.75	694,000	2.53	0.298	2720	186	460	10.58	39	364	8.36	79.0
1942	81.47	801,000	2.72	0.319	3140	207	550	12.65	45	431	9.90	78.3
1943	87.47	813,000	2.92	0.343	3190	216	618	14.20	—	—	—	—
1944	87.08	777,000	2.90	0.341	3040	238	677	15.53	—	—	—	—
1945	91.19	785,000	3.04	0.358	3080	213	635	14.58	—	—	—	—
1946	94.83	783,000	3.16	0.371	3070	147	456	10.48	—	—	—	—
1947	98.60	783,000	3.29	0.388	3070	160	516	11.88	—	—	—	—

TABLE VI.—Activated Sludge Plant Operating Data

Year	Sewage Treated (m.g.d.)	Return Sludge (%)	Aeration Period (hr.)	Air Used		5-Day B.O.D.		B.O.D. Loading[1]	B.O.D. Removal		
				Cu. Ft. per Gal.	Cu. Ft. per Lb. B.O.D. Removed	Influent (p.p.m.)	Effluent (p.p.m.)		P.P.M.	Per Cent	Lb. per Day
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1940	15.61	28.6	6.04	1.17	853	184	19	13.9	165	89.7	21,500
1941	13.28	23.3	7.41	1.24	860	186	14	11.2	172	92.2	19,000
1942	11.83	25.1	8.18	1.29	882	207	27	14.6	180	87.0	17,750
1943	12.51	23.1	7.85	1.29	780	216	18	16.4	198	91.6	20,600
1944	11.71	23.9	8.35	1.38	747	238	16	24.0	222	93.3	21,600
1945	10.64	21.5	9.40	1.24	745	213	14	24.2	199	93.4	17,650
1946	14.65	23.1	6.72	0.91	855	147	20	22.1	127	86.4	15,500
1947	12.62	18.7	8.10	1.01	833	160	15	23.0	145	90.6	15,200

Year	Suspended Solids			Mixed Liquor		Sludge Index Average	Power Consumption	
	Influent (p.p.m.)	Effluent (p.p.m.)	Removal (%)	D.O. (p.p.m.)	Susp. Solids (p.p.m.)		Kw-Hr. per Mil. Gal. Sewage	Kw-Hr. per Lb. 5-Day B.O.D. Removed
	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
1940	64	16	75	3.5	2190	125	682	0.492
1941	84	13	85	3.1	2229	99	744	0.516
1942	85	32	62	5.4	1731	261	798	0.536
1943	97	17	83	5.7	1681	254	789	0.480
1944	100	13	87	5.4	1190	357	850	0.423
1945	92	8	91	5.7	937	383	819	0.484
1946	67	8	88	5.9	990	246	604	0.571
1947	74	8	89	5.7	856	353	689	0.571

[1] Pounds per day B.O.D. in influent per 1000 lb. mixed liquor suspended solids per hour of aeration.

800 lb. per sq. in., was purchased. The ends of the distributor pipes were opened, a hose with a nozzle on the end of it was inserted in each pipe and water under the above-mentioned pressure was used to scour out the incrustation. This method of cleaning the pipes proved most effective.

Humus Tanks

The humus tanks have never given satisfactory results, the reason being that the sludge remains in the tanks and becomes septic. In passing through the tanks the B.O.D. of the filter effluent frequently increases and the nitrates and relative stability decrease. It is planned to provide these tanks with mechanical equipment to remove sludge continuously.

Activated Sludge Units

The activated sludge units were placed in operation on Nov. 27, 1939, and have been in service continuously since then except for a few short shutdown periods. The average yearly 5-day B.O.D. load (Table VI) has been high, ranging from 147 to 238 p.p.m. At the same time the effluent has been quite good with average yearly B.O.D. values varying from 14 to 27 p.p.m. and with suspended solids ranging from 8 to 32 p.p.m.

When the activated sludge units were placed in service, the keeping of

daily records was considered quite important. Samples of sewage, mixed liquor, and sludge are collected and analyzed every 4 hours. The results are plotted on graphic charts which are used in studying the performance of the plant.

The major operating problem with the activated sludge units has been with sludge bulking. During the first 2 years of operation serious bulking rarely occurred. The maximum sludge index during this period was 361. Bulking began in 1942 and has been observed at intervals since then. The average yearly sludge index has varied from 246 to 383 since January, 1942.

Many remedies have been tried to correct sludge bulking. Chlorine was used intermittently for over 4 years to control bulking, but the results obtained were unsatisfactory. The quantity used generally varied from 3 to 6 p.p.m. by weight of the return sludge. Applications as high as 15 p.p.m. were tried without success.

As indicated in Table VI, the average yearly volume of air used varied from 0.91 to 1.38 cu. ft. per gal. of sewage. It was thought that an excess volume of air might correct sludge bulking. Although the air was increased to 4.0 cu. ft. per gal. of sewage, with 12 p.p.m. of dissolved oxygen in the mixed liquor, bulking continued. Another corrective measure tried consisted of shutting off the sewage flow to the aeration tanks, with continued aeration of the mixed liquor for as long as 24 hours. At the same time a large volume of return sludge was pumped back into the aeration tanks to keep the sludge in a fresh condition. At times this procedure improved the settling characteristics of the sludge.

Activated sludge has been kept in good condition at some plants by maintaining a high solids concentration in the mixed liquor. In the light of this experience the solids in the mixed liquor were kept at 3000 to 3400 p.p.m. for a considerable period of time, but without success. Equally unsuccessful were efforts to treat a constant hourly quantity of sewage or a constant hourly organic load.

One practice that at times improved the condition of bulking sludge consisted of reducing the sewage flow to about 5 m.g.d. The flow was maintained at this rate for several days; if the sludge index decreased, the flow was increased in increments of about 1 m.g.d every few days until conditions were again normal.

Although maintaining less than 1000 p.p.m. of suspended solids in the mixed liquor has not corrected sludge bulking, it has been possible to produce a final effluent containing fewer suspended solids when bulking does occur. It is interesting to note that the suspended solids in the final effluent averaged 8 p.p.m. for the 3-year period from 1945 to 1947, inclusive, when the suspended solids in the mixed liquor averaged 928 p.p.m., as compared with 18 p.p.m. of suspended solids in the effluent during the preceding 5 years when the mixed liquor contained an average of 1804 p.p.m. of suspended solids.

During the 8 years that the aeration tanks have been in service, they have been dewatered twice. There has been no apparent clogging of the diffuser plates. The application of air to the mixed liquor seems quite uniform throughout both aeration tanks.

A detailed study was made to determine what operating conditions affected the removal of B.O.D. Daily, monthly, and yearly operating data were studied. No correlation could be found between the B.O.D. removal and (1) the amount of air used per gallon of sewage, (2) the suspended solids in the mixed liquor, (3) the detention period in the aeration tanks, or (4) the volume of air used per pound of B.O.D. removed. The loading on the activated sludge plant varied from a yearly average of 11.2 to 24.2 lb. of B.O.D. in the aeration

tank influent per day per 1000 lb. of suspended solids in the mixed liquor per hour of aeration. One would expect that the percentage removal of B.O.D. would vary inversely with this loading (1). Such, however, was not the case. For example, the percentage removal was greater in 1944 and 1945 with a high loading than in 1940 and 1941 with a considerably lower loading.

One interesting fact is that as satisfactory an effluent was obtained when the sludge index was high as when it was low. For example, the 5-day B.O.D. and suspended solids in the effluent for 1945 were 14 and 8 p.p.m., respectively, with an average sludge index of 383, as compared with a B.O.D. of 14 p.p.m. and a suspended solids content of 13 p.p.m. during 1941 with a sludge index of 99.

Operating data relating to the two activated sludge thickening tanks are given in Table VII. During 1940 and 1941 considerable thickening of the sludge was effected. For example, in 1941 the solids content of the sludge was increased from 1.1 to 2.1 per cent. During 1947, the solids in the unthickened and thickened sludge were 0.57 and 0.64 per cent respectively. It is most probable that the high sludge index from 1943 to 1947, inclusive, was the reason that both the unthickened and the thickened sludge had a low solids content.

The two thickening tanks were designed to thicken the excess activated sludge resulting from the treatment of an average flow of 40 m.g.d. of sewage. Each tank was designed to handle 160,000 gal. daily of excess sludge and provide a detention period of 2.4 hours at this flow. As the volume of excess sludge generally has been in excess of this amount, both tanks were often used.

The amount of chlorine added to the supernatant of the thickening tanks has varied from a yearly average of 4.8 to 11.4 p.p.m.

Chlorination of Final Effluent

The sewage works effluent is chlorinated during the summer. One-ton chlorine cylinders are delivered to the sewage works by truck and are stored on an outdoor wooden platform that holds 24 cylinders. Sixteen cylinders in two banks are usually in service. Two 1-in. interconnected manifold pipe lines connect the two groups of cylinders with three rotometers. Having the piping and the rotometers in triplicate permits the repairing of one of them without the necessity of discontinuing chlorinating operations. The discharge piping from the rotometers connects with an ejector, operated by

TABLE VII.—Operating Data of Activated Sludge Thickening Tanks

Year	Flow of Sludge		Dry Solids in Sludge		Volatile Matter in Thickened Sludge (dry basis, %)	Effluent from Thickener Tanks	
	To Thickener Tanks (gal. per m.g. sewage)	From Thickener Tanks (gal. per m.g. sewage)	To Thickener Tanks (%)	From Thickener Tanks (%)		Suspended Solids (p.p.m.)	Cl_2 (p.p.m.)
1940	—	5,400	0.9	1.9	80.9	96	4.8
1941	—	4,200	1.1	2.1	79.2	81	11.4
1942	—	4,500	0.9	1.4	80.1	197	7.3
1943	—	12,100	0.9	1.1	—	230	9.1
1944	24,900	20,100	0.6	0.8	—	89	10.7
1945	29,100	23,420	0.6	0.7	—	116	10.3
1946	25,000	19,600	0.51	0.65	77.6	42	9.3
1947	24,500	20,600	0.57	0.64	79.4	61	8.5

TABLE VIII.—Quantity of Chlorine Used to Treat Final Effluent

Year	Sewage Treated (m.g.d.)	Chlorinating Period (days)	Chlorine Dosage (p.p.m.)
1945	85.69	151	6.11
1946	91.15	148	6.39
1947	95.65	150	5.86

settled sewage, that produces a partial vacuum in this piping. The settled sewage containing the dissolved chlorine flows through two 3-in. micarta pipes, which are submerged in the final effluent conduit. There are a number of ¼-in. holes in these pipes through which the dissolved chlorine discharges.

During the season when chlorine is being used, an operator visits the chlorinating station every 4 hours and records the amount of chlorine used. He determines the residual chlorine in the effluent and adjusts the chlorinator to maintain a residual of about 0.5 p.p.m., after a 10-minute contact period.

Table VIII gives the amount of chlorine used from 1945 to 1947, inclusive. During the 3 years of operation, an average of approximately 4650 lb. of chlorine was used daily. The average dosage during each year varied from 5.86 to 6.39 p.p.m. Once a week samples of the effluent were examined for coliform bacteria. The results were usually negative. Occasional samples had a M.P.N. of 25 per ml.

Sludge Digestion

The sludge from the primary settling tanks flows by gravity into an open well in the Sludge Control Station and is pumped from there into either the three heated or the ten unheated digesters. During the early operating period of the activated sludge plant the thickened activated sludge was also pumped into the above mentioned well. This method of handling the activated sludge was soon discontinued, as it contained large volumes of water which occupied considerable space in the digesters. This sludge is now pumped into the raw sewage and is removed from the primary settling tanks. Pertinent data concerning the raw sludge added to the heated digesters are given in Table IX.

The variation in the amount of raw sludge pumped into the digesters has been due to the necessity of taking the digesters out of service from time to time. During the 8-year period from 1940 to 1947, inclusive, one of the three heated digesters has been out of service an average of 82.4 days a year, or 7.5 per cent of the time. The operation of the digesters has been in-

TABLE IX.—Operating Data for Heated Sludge Digesters

Year	Est. Pop. Served	Tank Capacity Available		Digestion Period (days)	Raw Sludge Added				Sludge Withdrawn				
									Thick Sludge			Thin Sludge	
		Cu. Ft.	Cu. Ft. per Cap.		Dry Solids Daily (tons)	Lb. Dry Solids per Cu. Ft. per Day	Solids Content (%)	Vol. Solids, Dry Basis (%)	Dry Solids Daily (tons)	Solids Content (%)	Vol. Solids, Dry Basis (%)	Dry Solids Daily (tons)	Solids Content (%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1940	530,000	554,700	1.04	15	46.05	0.17	3.9	81.2	0.81	7.5	58.2	18.8	1.6
1941	543,000	515,800	0.95	13	44.56	0.17	3.6	79.2	3.04	9.2	56.0	26.5	2.2
1942	556,000	535,800	0.96	13	45.18	0.17	3.5	81.9	2.06	5.8	68.2	23.7	1.9
1943	447,000	496,000	1.11	15	36.96	0.15	3.5	84.1	0.74	7.1	68.2	18.8	1.8
1944	481,000	554,700	1.15	15	43.70	0.16	3.8	83.5	0.11	7.0	76.4	20.6	1.8
1945	509,000	554,700	1.09	15	39.65	0.14	3.3	82.0	—	—	—	22.9	1.9
1946	406,000	466,900	1.15	15	29.01	0.13	3.0	79.6	—	—	—	23.2	2.4
1947	294,300	426,900	1.45	20	24.64	0.12	3.7	78.3	—	—	—	15.3	2.3

terrupted for a number of reasons. It has been necessary to empty two of the digesters to remove large accumulations of grit that prevented the rotating mechanism from operating. On another occasion the 6-in. heating coils in one of the tanks became dislodged from the supports and were replaced. The cast iron housing containing the drive gear for one of the digesters broke and was repaired, and the steel liners in the ball-bearing race at the top of the sludge stirring mechanism broke and the race had to be replaced.

From 1940 to 1944, inclusive, a somewhat concentrated sludge was withdrawn at regular intervals from the bottom of the heated digesters. The dry solids and volatile content values of the withdrawn sludge are shown in Table IX. During the first 5 years of operation thin sludge containing a yearly average from 1.6 to 2.2 per cent solids was drawn from an intermediate zone in the tanks, and during the last 3 years of operation sludge was removed only from this intermediate zone. All sludge drawn from the heated tanks was pumped into 10 unheated open tanks.

The digesters were heated by pumping hot water through the 6-in. pipe coils in the tanks. The quantity of water pumped through each pipe coil varied from about 60 to 170 g.p.m., largely depending on the season of the year. The temperature of the hot water as it entered the pipe coils was normally maintained below 140° F., and the amount of heat added to each tank varied from approximately 400,000 to 2,800,000 B.t.u. per hr. The average yearly temperature in the three heated digesters ranged from 71.9° to 85.0° F. Temperatures varying from 90° to 100° F. were maintained in the tanks for considerable periods of time.

The average yearly heat transfer through the pipe coils (Table X) varied from 10.7 to 19.4 B.t.u. per sq. ft. of pipe surface per hour per degree temperature difference. Since 1941 there has been a gradual decrease in the heat transfer due, undoubtedly, to scale forming on the outside of the pipes.

TABLE X.—Heat Transfer Through Pipe Coils in Sludge Digesters 1, 2, and 3

Year	Tank Temperature (°F.)	Heat Transfer Through Pipe Coils (B.t.u./sq. ft./hr./degree temp. diff.)
1940	81.4	16.5
1941	78.2	19.4
1942	84.3	17.1
1943	81.8	12.2
1944	85.0	10.7
1945	79.3	11.8
1946	79.2	11.5
1947	71.9	—

When heated digester No. 1 was out of service for repairs during the latter part of 1947 the thickness of the scale on the heating coils was determined (Table XI). The hot water enters the top coil and leaves through the bottom coil. The scale varied from 1/16 to 1/2

TABLE XI.—Thickness of Scale on 6-Inch Heating Coil in Sludge Digester No. 1 *

Distance From Inlet Along Pipe (ft.)	Scale Thickness			Remarks
	Top (in.)	Sides (in.)	Bottom (in.)	
0	3/16	1/4	3/8	Beginning 1st coil
78	0	3/16	1/2	
154	1/16	1/8	1/4	
230	1/16	1/8	3/8	
304	3/16	3/16	1/2	Beginning 2nd coil
382	0	1/4	1/4	
458	1/16	1/4	1/4	
534	1/16	1/4	1/4	
608	1/8	1/4	3/8	Beginning 3rd coil
686	1/16	3/16	1/4	
762	1/16	1/8	3/16	
838	1/16	1/8	3/16	
912	1/8	3/16	3/16	Beginning 4th coil
990	0	1/8	3/16	
1066	1/16	1/8	3/16	
1142	1/16	1/8	1/8	
1213	Tr.	1/16	1/16	

* Tank in continuous service for 11 years.

TABLE XII.—Gas Production from Digesters 1, 2, and 3

Year	Quantity				CH_4 Content (%)
	Cu. Ft. Daily	Tons Daily	Cu. Ft. per Lb. Vol. Matter Added	Cu. Ft. per Cap.	
1940	790,200	28.2	10.6	1.49	66.1
1941	842,600	30.2	11.9	1.49	65.6
1942	904,900	32.3	12.4	1.56	65.9
1943	744,100	27.0	12.0	1.66	64.7
1944	778,700	27.5	10.7	1.62	66.7
1945	779,500	27.9	12.0	1.53	66.3
1946	642,500	23.0	14.0	1.58	65.8
1947	442,400	15.7	10.5	1.50	66.6

in. in thickness and was thickest on the bottom of the pipe and thinnest on the top. The scale formed over a period of 12 years and 1 month, during which time the tank was out of service 13 months. The heat transfer through the heating coils during the last four months prior to shutting down the tank dropped to 2.7 B.t.u. per sq. ft. of heating surface per hour per degree of temperature differential.

The gas production from the three heated digesters has varied (Table XII) from a yearly average of 442,400 cu. ft. per day in 1947 to 904,900 cu. ft. per day in 1942. That large quantities of volatile solids are being destroyed is evidenced by the weight of this gas. In 1942, 32.3 tons of gas were produced daily, or 71.4 per cent of the dry sludge solids added to the digesters. It should be remembered that the weight of the gas evolved from digesting sludge is greater by 15 per cent, or more, than the loss in weight of the sludge (2). The rate of gas production varied from 10.5 to 14.0 cu. ft. per lb. of volatile matter in the raw sludge added to the digesters, or from 1.49 to 1.66 cu. ft. per capita served. The per capita gas production is greater than normal, as the sewage is relatively strong, with a somewhat high solids content.

It is important to know with what frequency low gas productions are to be expected at sewage works, especially where most or all of the gas is used. To answer this question the day-by-day gas production during 1940 was studied. This year was selected as there was an uninterrupted flow of gas from all three of the digesters throughout the year. The results of this study were plotted on Hazen probability paper and are shown in Figure 7. The gas production averaged 790,200 cu. ft. daily and can be expected to be less than 485,000 cu. ft. daily for 0.5 per cent of the time, or 1.8 days a year, and less than 570,000 cu. ft. daily for 5.0 per cent of the time, or 18¼ days a year. These productions can be looked for only if all three digesters are in operation and are receiving the amount of solids digested during 1940.

The methane content of the gas has

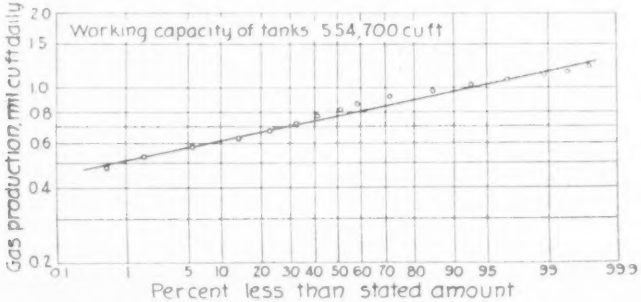

FIGURE 7.—Range and frequency of gas production from three heated digesters during 1940.

TABLE XIII.—Unheated Digester Operating Data

Year	Sludge to Digesters								Digestion Period (days)
	From Primary Tanks				From Heated Digesters				
	Quantity		Solids Content (%)	Vol. Solids, Dry Basis (%)	Quantity		Solids Content (%)	Vol. Solids, Dry Basis (%)	
	Mil. Gal.	Dry Solids (tons daily)			Mil. Gal.	Dry Solids (tons daily)			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1940	52.99	24.0	3.9	81.2	0.93	0.81	7.5	58.2	100
1941	54.59	22.8	3.6	79.2	2.83	3.04	9.2	56.0	94
1942	72.90	29.7	3.5	81.9	3.04	2.06	5.8	68.2	72
1943	97.89	39.9	3.5	84.1	0.89	0.74	7.1	68.2	55
1944	92.95	41.2	3.8	83.5	0.14	0.11	7.0	76.4	58
1945	85.30	32.9	3.3	82.0	103.2	22.9	1.9	—	29
1946	107.74	37.6	3.0	79.6	83.1	23.2	2.4	—	29
1947	122.28	52.9	3.7	78.3	57.2	15.3	2.3	—	30

Year	Sludge from Digesters												
	To Vacuum Filters				To Sludge Drying Beds				To Lagoons			Total Dry Solids	
	Quantity		Dry Solids (%)	Vol. Solids, Dry Basis (%)	Quantity		Dry Solids (%)	Vol. Solids, Dry Basis (%)	Quantity		Dry Solids (%)		
	Mil. Gal.	Dry Solids (tons daily[1])			Mil. Gal.	Dry Solids (tons daily)			Mil. Gal.	Dry Solids (tons daily)		Tons Daily	Tons per M.G. Sewage
(1)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
1940	33.81	26.0	5.2	58.3	—	—	—	—	—	—	—	26.0	0.29
1941	36.56	30.3	4.5	59.5	12.75	3.49	2.4	67.8	8.64	3.52	3.5	37.3	0.42
1942	46.04	31.8	4.6	60.8	3.66	1.25	3.0	63.3	—	—	—	33.1	0.35
1943	53.71	28.9	3.6	67.0	12.74	5.23	3.6	67.8	3.11	0.69	1.9	34.8	0.35
1944	59.74	35.7	3.4	68.7	5.07	1.77	3.0	70.3	8.54	2.88	2.9	40.4	0.39
1945	48.32	34.8	3.8	68.6	4.40	2.13	4.6	70.3	18.31	6.43	3.1	43.4	0.40
1946	41.43	31.6	4.1	61.1	1.92	0.88	4.0	66.1	11.41	4.24	3.2	36.7	0.32
1947	53.50	41.3	3.6	62.8	8.85	3.92	2.8	65.4	1.45	0.39	2.3	45.6	0.39

[1] Tonnage based on a 365-day year.

varied from a yearly average of 64.7 to 66.7 per cent. Numerous analyses of the gas showed the H_2S content varied from 4.1 to 6.4 grains per 100 cu. ft.

Details regarding the operation of the unheated sludge tanks are given in Table XIII. Raw sludge that was not pumped into the heated digesters was added to these tanks. The average yearly additions of raw sludge have varied from 22.8 to 52.9 dry tons daily. When all three of the heated digesters were in service, the quantity was a minimum. All of the sludge from the heated digesters is pumped into the unheated tanks, which thus serve to a limited extent as secondary digesters. The digestion period in these tanks has varied from 29 to 100 days.

As indicated in Table XIII, the weight of dry solids drawn from the unheated digesters, exclusive of the year 1940 which is not typical, has varied from 33.1 to 45.6 tons daily, or

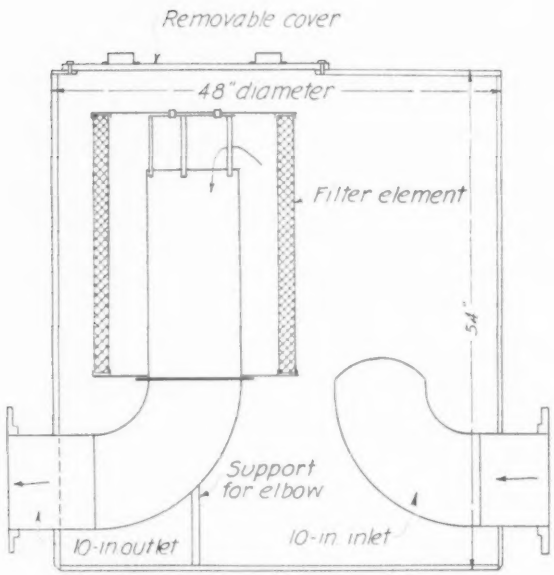

FIGURE 8.—Moisture trap.

from 0.32 to 0.42 ton per m.g. of sewage.

Sludge Filtration

After the vacuum filters were put in service in 1938, a few alterations in the design of the equipment were made to improve operating conditions. Chief among these was the method of mixing the coagulant and the sludge. As originally planned, the mixing was to be done by blowing air through several diffuser tubes suspended in the sludge. This method of mixing proved ineffectual and was superseded by slow-speed paddles.

The first two filters installed were designed to operate at speeds that could be varied from 30 to 180 sec. per revolution. Experience has indicated that a drier cake and better results were obtainable by operating the filters at slow speeds. The filters have been equipped with slower speed drive motors, operating at speeds from 60 to 360 sec. per revolution.

The trough of each filter was provided with a float and a float switch for ringing an alarm if the sludge becomes excessively high. These floats were unsatisfactory as they became coated with sludge solids and failed to operate properly. They have been replaced with insulated rod-like probes that have none of the defects of the floats.

Although moisture traps were installed between the filters and the vacuum pumps and were placed approximately 20 ft. above the vacuum receivers, water accumulated in the vacuum pumps, which are of the reciprocating type. To prevent this, a specially designed moisture trap (Figure 8) was installed in the vacuum piping leading to the vacuum pumps.

With the exception of one test made with canton flannel, which proved unsatisfactory, all of the filter cloths have been made of 12-oz. wool. During the 9-year period that the filters have been in operation, the cloths have had an average life of 1496 hours.

TABLE XIV.—Sludge Conditioning and Filtering Data

Year	Unelutriated Sludge Alkalinity[1] (p.p.m.)	Ratio of Elutriating Water to Sludge	Elutriated Sludge		Elutriate		Conditioner,[2] Per Cent of Dry Solids	Filter Cake				Operating Period (days)
			Solids (p.p.m.)	Alkalinity (p.p.m.)	5-Day B.O.D. (p.p.m.)	Suspended Solids (p.p.m.)		Dry Solids Output			Moisture (%)	
								Total (tons)	Per Day (tons)[2]	Lb. per Sq. Ft. per Hr.		
1940	2710	7.9	4.9	504	84	277	5.04	9,572	32.56	4.97	77.2	294
1941	2410	7.2	5.1	486	72	236	5.73	11,062	37.37	4.77	76.5	296
1942	2540	7.0	4.9	515	83	238	5.98	11,599	38.92	4.49	76.4	298
1943	2920	7.2	4.5	562	133	316	6.03	10,524	35.43	3.85	76.7	297
1944	5201	6.7	5.3	779	175	123	4.98	13,007	43.65	5.13	76.7	298
1945	3565	6.1	5.9	664	169	340	4.97	12,665	43.98	5.86	75.0	288
1946	2384	7.4	5.7	384	96	209	6.19	11,523	39.87	4.30	75.4	289
1947	2210	6.5	5.8	437	127	280	5.51	15,094	51.34	4.20	73.8	294
Average	2992	7.0	5.3	541	117	252	5.57	11,681	40.39	4.70	76.0	294

[1] For quantity and analysis of unelutriated sludge see Table XIII.
[2] Average daily output based on actual number of days of operation.
[3] Anhydrous chlorinated copperas.

The vacuum filtrate piping in the interior of the filters consists of brass fittings and copper pipe. Some of this pipe started to fail at the threaded connections after about 6 year's service. Consideration is being given to the use of some type of plastic piping for this service.

The quantity and the analysis of the sludge that was filtered is given in Table XIII. The volume of sludge filtered varied from a minimum of 33.81 m.g. in 1940 to a maximum of 59.74 m.g. in 1944, and the solids and volatile content were as shown in Table XIII. Sludge conditioning and filtration data are given in Table XIV.

Sludge Drying Beds and Lagoons

To provide room in the digesters sludge was drawn to the drying beds and lagoons from time to time. This material was usually low in solids. At no time during the 8-year period was the sludge removed from the beds after it had dried. One year's application was superimposed on that of the previous year.

Filter Cake Disposal

All but a small portion of the filter cake was piled on the sewage works

TABLE XV.—Cost of Sewage Treatment

Year	Fixed Costs			Operating Costs			Fixed and Operating Costs		
	Total ($)	Per M.G. of Sewage ($)	Per Capita Per Year ($)	Total ($)	Per M.G. of Sewage ($)	Per Capita Per Year ($)	Total ($)	Per M.G. of Sewage ($)	Per Capita Per Year ($)
1940	546,194	16.90	0.68	180,373	5.58	0.22	726,567	22.48	0.90
1941	546,194	16.74	0.67	190,990	5.85	0.23	737,184	22.59	0.90
1942	561,401	16.41	0.61	195,702	5.72	0.21	757,103	22.13	0.82
1943	561,409	15.38	0.60	206,150	5.65	0.22	767,559	21.03	0.82
1944	561,409	14.64	0.60	251,797	6.56	0.27	813,205	21.20	0.87
1945	561,800	14.23	0.60	271,652	6.88	0.29	833,452	21.11	0.89
1946	561,879	13.62	0.60	287,230	6.96	0.31	849,109	20.58	0.91
1947	566,911	13.10	0.60	312,208	7.43	0.34	888,119	20.53	0.94

TABLE XVI.—Operating and Maintenance Costs for 1947

Treatment Unit	Operating Costs ($)	Maintenance Costs ($)	Operating and Maintenance Costs ($)
Mechanically-Cleaned Screens	13,509	5,388	18,897
Grit Chambers	7,163	3,144	10,307
Preliminary Settling Tanks	20,052	10,865	30,917
Fine Screens	8,713	4,254	12,967
Trickling Filters	12,496	3,399	15,895
Humus Tanks	878	77	955
Activated Sludge Units	73,651	6,748	80,399
Chlorinating Final Effluent	21,652	2,854	24,506
Sludge Digestion Tanks	16,263	11,351	27,614
Vacuum Filters	41,803	23,959	65,762
Final Sludge Disposal	18,216	5,271	23,487
Care of Grounds	8,620	882	9,502
Total	243,016	78,192	321,208

property. A portable belt conveyor deposited the sludge in a pile nearby after leaving the filter building, and a 5-ton gasoline-driven crane, equipped with a ½-yd. bucket, loaded the sludge on trucks. Three trucks were generally required to haul the sludge away from the building and deposit it on the sewage plant grounds. A small quantity was used by gardeners, farmers, and others for fertilizer purposes. A modern heat-drying plant will be built to dry the material for use as a base in making fertilizer.

Corrosion of Metal

The corrosion of metal surfaces has been a difficult problem at the sewage plant. Of the various metals that have been used, steel and copper have deteriorated the most. At some locations in the plant the rate of corrosion is greater than at others. Steel gratings on the trickling filters that were exposed to the spray of sewage were very badly rusted after about 10 years of service. These gratings have been replaced by cast iron, which is giving excellent service.

Copper gutters and downspouts on many of the buildings have deteriorated. Fly screens made of copper and aluminum proved unsatisfactory. Bronze and monel have been used for numerous purposes with considerable success. Cast iron is also quite serviceable.

Ferrous and ferric solutions are difficult to handle. Rubber-lined pipe and iron pipe containing a high silica content have proved satisfactory when handling these solutions. Chlorine gas and solutions containing chlorine are also highly corrosive. Rubber-lined steel pipe, hard rubber pipe, and micarta pipe have given good results when subjected to the action of chlorine. However, hard rubber pipe is easily broken and micarta pipe may fail if it is subjected to heavy strains.

Treatment Costs

The cost of sewage treatment for each year from 1940 to 1947, inclusive, is given in Table XV. The fixed costs varied from $13.10 to $16.90 per m.g. of sewage and from $0.60 to $0.68 per capita yearly. These fixed costs are based on the first cost of the plant increasing from $9,753,465 in 1940 to $10,123,403 in 1947. An interest rate of 4.1 per cent has been used, which is the average rate paid on stocks sold to finance the construction of the plant. Depreciation based on the sinking-fund method is taken to be 1.5 per cent yearly.

Since 1940 operating and mainte-

TABLE XVII.—Cost of Sludge Digestion

Year	Raw Sludge Handled, Dry Solids (tons)	Cost of Digestion Tanks ($)	Fixed Charges		Operating and Maintenance Costs		Total Costs	
			Total ($)	Per Ton of Dry Solids ($)	Total ($)	Per Ton of Dry Solids ($)	Total ($)	Per Ton of Dry Solids ($)
1940	25,610	685,396	36,189	1.41	15,650	0.61	51,839	2.02
1941	24,610	685,396	36,189	1.47	17,327	0.70	53,516	2.17
1942	27,310	685,396	36,189	1.33	19,900	0.72	56,089	2.05
1943	28,030	685,396	36,189	1.29	19,374	0.69	55,563	1.98
1944	30,980	685,396	36,189	1.17	21,018	0.68	57,207	1.85
1945	26,430	685,396	36,189	1.37	19,978	0.76	56,167	2.13
1946	24,320	685,396	36,189	1.49	20,079	0.82	56,268	2.31
1947	28,207	685,396	36,189	1.28	27,614	0.98	63,803	2.26

nance costs have increased from $5.58 to $7.43 per m.g. and from $0.22 to $0.34 per capita yearly. During this 8-year period the annual operating costs have increased approximately 73 per cent, due to the increased cost of labor and materials. For example, common labor was paid $0.45 an hour in 1940 and $0.96 in 1947. Electric current cost $0.0088 in 1940 and $0.0106 in 1947, an increase of a little over 20 per cent. The total cost of treatment, including fixed and operating costs, ranged from $20.53 to $22.59 per m.g. and from $0.82 to $0.94 per capita per year.

The cost of operating and maintaining the individual treatment units during 1947 is given in Table XVI. The most expensive to operate were the activated sludge units, which cost $17.45 per m.g. The next most expensive consisted of chlorinating the sewage at a cost of $0.74 per m.g.

The cost of digesting and filtering the sludge is given in Tables XVII and XVIII. Sludge digestion costs varied from $1.85 to $2.31 per ton of dry solids and averaged $2.10. About two-thirds of this cost consisted of fixed charges and the remaining third involved operating and maintenance costs. The cost of filtering the sludge ranged from $5.68 to $7.13 per ton of dry solids and averaged $6.09. Fixed charges accounted for approximately one third of these costs, and operating and maintenance costs two-thirds.

TABLE XVIII.—Cost of Filtering Sludge

Year	Quantity Dry Solids Filtered (tons)	Cost of Filtering Equipment ($)	Fixed Charges		Operating and Maintenance Costs		Total Costs	
			Total ($)	Per Ton of Dry Solids ($)	Total ($)	Per Ton of Dry Solids ($)	Total ($)	Per Ton of Dry Solids ($)
1940	9,572	360,772	23,822	2.49	34,463	3.60	58,285	6.09
1941	11,062	362,035	23,906	2.16	41,123	3.72	65,029	5.88
1942	11,599	363,956	24,055	2.07	41,833	3.61	65,888	5.68
1943	10,524	365,170	24,118	2.29	40,214	3.82	64,332	6.11
1944	13,007	365,170	24,118	1.85	52,040	4.00	76,158	5.85
1945	12,665	365,170	24,118	1.90	51,051	4.03	75,169	5.93
1946	11,523	366,944	24,262	2.11	57,839	5.02	82,101	7.13
1947	15,094	366,944	24,262	1.61	65.762	4.35	90,024	5.96

Acknowledgments

The sewage plant is under the general direction of P. L. Holland, director, Department of Public Works, and John J. Hunt, sewerage engineer. R. J. Trautman, principal associate engineer, has general supervision over the plant and G. K. Armeling is the plant superintendent.

References

1. Fair, Gordon M. *et al.*, "Sewage Treatment at Military Installations—Summary and Conclusions." THIS JOURNAL, **20**, 52 (Jan., 1948).
2. Buswell, A. M., and C. S. Boruff, "The Relation Between the Chemical Composition of Organic Matter and the Quality and Quantity of Gas Produced During Sludge Digestion." *Ibid.*, **4**, 454 (May, 1932).

COOPERATIVE EFFORT SOLVES PAPER WASTE PROBLEM

By Walter A. Sperry

Superintendent, Aurora (Ill.) Sanitary District

In the latter part of 1943 the volume of primary sludge received by the Aurora Sanitary District seemed unusually large. In appearance, the raw sludge was particularly black and fibrous. For some time, also, the digester runs between discharges to the drying beds had been shorter than usual, which meant an unusual volume of sludge handling from the beds to the storage pile. The pounds of equivalent dry primary sludge for the July–December 1943 period averaged 7550 lb. per day and exceeded by 28 per cent the daily poundage of sludge received the forepart of the year. Also, the average volatile matter increased slightly from 72.0 to 73.8 per cent. After considering the matter, it seemed apparent that a local paper mill was the source of an excessive volume of waste. This mill converts all manner of waste paper into book board.

Original Waste Control Measures

At the time of building the original Sanitary District intercepter the paper mill, at an expense of $10,000, installed an Oliver filter to protect the District against an unusual wastage of fiber in their wash-water. Through the years 1928 to 1943 no particular attention was paid to this source of industrial waste and no study was made as to its volume or content, it being known that the Oliver filter was in continuous use and it was believed that this was a reasonable gesture on the part of the mill to reduce the waste discharged to the Sanitary District sewer.

Late in 1943 a conference was held with the paper company officials. The sewage plant operation data and the paper mill records were reviewed and the opinion advanced that the mill waste losses were excessive. The mill officials had suspected this for some time and were both friendly and cooperative. As a result of the conference a systematic study of the mill waste was undertaken.

Waste Survey Procedure

In considering the arrangements for this survey it was realized that it would be necessary for the mill employees to perform the work of recording weir measurements and collecting samples. This meant that the sampling scheme adopted had to be made simple, convenient, and more or less

fool-proof if it were to be successful, so that a minimum amount of time would be required by company employees and the continuity of work at the mill would not be interrupted. These considerations dictated the arrangements made with the mill.

The mill operated four paper machines. Spillage from these machines and wastes from other parts of the plant were collected by floor drains into a channel of rectangular section which meandered through the plant and eventually discharged into the District's intercepter. In making the wastes survey two important steps were necessary; one, to obtain the volume of the wastes; and the other, to obtain a representative sample of the wastes for suspended solids determinations.

Flow Measurements

The most desirable method of measuring the volume of flow would have been by means of a 90° V-notch weir, placed in the channel discharging to the intercepter. It was discovered, however, that the only place where such a weir could be installed was in a deep manhole some distance outside the building. It was not practical to do this, due to the fact that the samples were to be taken over the entire year, and each weir measurement would have required several minutes spent in climbing in and out of a manhole some distance from the plant. A compromise was made, therefore, and a rectangular weir was installed in the drain channel within the mill, at a point where all the wastes from the mill must pass. By using a measuring stick with a ruler at the top and a sharpened point on the lower end, and by establishing a fixed reference point, it was a simple matter for a plant employee to touch the surface of the flow with the measuring stick point, which acted as a hook gage, and read the flow over the weir from the upper scale at the reference point. For short periods, V-notch weir measurements were made in parallel with the rectangular weir. These results indicated that the rectangular weir gave readings about 15 per cent low. While it was agreed that this was not the best method for measuring the flow it did give a relative and comparative record which was sufficient for the purpose of the survey. Occasionally, the mill employees had to be cautioned to keep sand and other debris from accumulating back of the weir, and this they did fairly well.

For handling the samples, two crates were provided which had convenient handles and into which six 1-qt. milk bottles would fit. The bottles were labeled for the days of the week. A small measure was also provided which had a capacity of about one-half pint so that four of these measures would approximately fill the milk bottle for a given day.

A sampling schedule was arranged so that one sample would be collected at 6-hour intervals over the 24 hours of the day. Each day's flow was thus represented by four samples and the time at which the samples were taken was based on the mill routine of shift changes and wash-up time. With each sample a weir measurement was made and noted. The four-sample daily schedule adopted was a compromise between wisdom of not multiplying the work of the mill employees unduly and the desirability of a larger number of samples. However, over a long period the results were judged to be reasonably comparative. Finally, through the friendly cooperation of the Fire Department stations arrangements were made whereby the week's samples were left there to be picked up by the District in exchange for the previous week's sample bottle case. This, also, was arranged for the sake of convenience.

Survey Results

This general sampling setup was faithfully maintained by the mill and proved very satisfactory over a period

of 4½ years. During that time, as the accompanying table indicates, a very rewarding improvement took place. The analytical work required at the District laboratory does not consume more than 1½ hours per week for the analyses, recording, and reporting.

It is important to note that the mill was given a written report of their daily operating results each week. This was a wise procedure since the mill thus received an immediate report of their good and bad days and could note any progress towards improved conditions. The District kept a running graph of the results of these tests, and at 6-month and yearly intervals the mill was given a complete report as to the amount of waste and, more particularly, the improvements that were effected from day to day.

At the outset, early in 1944, the mill fiber waste was considerable. For example, for the week of May 29 to June 3, the suspended solids content was 1360 p.p.m., the flow for the week was 1.88 m.g., and the fiber loss amounted to 10.6 tons. In 1948, for the week of May 10 to 14, the suspended solids were 747 p.p.m., the flow 0.59 m.g., and the fiber loss 1.8 tons. This contrast emphasizes the extent of the waste loss reductions.

The fiber losses which were disclosed by the initial weekly and semiannual analytical reports were so large that the company voluntarily carried out a series of waste reduction improvements. At that time paper fiber reportedly was worth about $30 per ton ready for the paper machines.

The company made many voluntary efforts to reduce fiber losses. During 1944 a study was made of the Oliver filter in order to improve its operation. In the early part of 1945 the company augmented the Oliver filter with a "Saveall," which considerably improved operations and made possible waste salvage during periods when repairs on the filter or "Saveall" were required. In the meantime the company was urged to consider providing a sump pit and pump in which the overflows from the paper machines and the wastes from other operations could be collected, since it was observed that this material, flooding to the floor, flowed over the floor and into the drainage channel below, thus bypassing the "Saveall" and Oliver filter. A sump pit and pump was finally installed and was placed in operation in June, 1947.

Later, in 1947, the amount of fiber salvaged had increased to a point where the company added a much larger "Saveall" to work in conjunction with the "Saveall" installed in 1945. In February, 1946, the number of paper machines was increased from 4 to 5, so that had the above discussed improvements not been made the wasteage would have been considerably increased. By this time, however, the control of the wastes was such that despite the additional paper machine, which accounts for the in-

TABLE I.—Characteristics of Paper Mill Wastes, Aurora, Ill.

Item	Year					Per Cent Reduction 1944–1948
	1944	1945	1946	1947	1948	
Days of mill operation	267	258	275	273	260	—
Average suspended solids of wastes (p.p.m.)	1460	1118	778	800	828	43.2
Total yearly waste flow (m.g.)	60.0	40.4	53.9	33.0	23.6	60.6
Total yearly fiber loss (tons)	357.9	189.1	174.1	102.2	82.0	77.1
Average fiber loss per day (lb.)	2680	1460	1260	745	640	76.1
Waste flow per week (m.g.)	1.35	0.94	3.7	2.1	1.6	80.0
Average fiber loss per week (tons)	8.0	4.3	1.17	0.67	0.46	66.2

crease in flow noted in 1946, the suspended matter dropped considerably, the reduction being enough to reduce the tonnage of waste over the preceding year.

Characteristics of Waste

Table I shows the characteristics of the mill wastes for the years 1944–1948. Data for the year 1948 are predicted on the assumption that the results for the entire year approximated those obtained during the first 6 months.

Conclusions

This industrial waste control experience has been a very satisfactory one for the District. The relations between the District and the paper mill officials have been more than friendly. Certainly for the small volume of work undertaken at the District Laboratory the returns have been very large. Not only has there been a marked reduction in the paper waste load discharged to the District's treatment facilities, but the fiber losses, established by the weekly analytical reports, have encouraged the paper mill officials to spend considerable money for waste reduction improvements. It is believed that where similar industrial waste problems arise, the manner in which a waste control program is set up and the type of approach used towards management will determine the degree of cooperation extended by industry.

Good public relations are established when both parties to the transaction can show a profit.

DIGESTER CLEANING AT FORT WAYNE

By Ralph A. Hoot

Superintendent, Fort Wayne (Ind.) Sewage Treatment Works

The Fort Wayne activated sludge plant has four digesters, each 90 ft. in diameter, with a 29-ft. effective depth and a volume of 1,400,000 gallons. These digesters are equipped with six 3-in. heating coils located 2 ft. from the wall of the tank, which provides 1700 ft. of coil length for each digester. As would be expected, the coils gradually become coated with sludge, with the result that the transfer of heat is materially diminished. The consequence is that periodically the tanks have to be taken out of service, cleaned, and the coils de-scaled.

Two digesters were cleaned in November 1948. Pumping was started on the first full digester on Monday, Nov. 1. By 8 P.M. the floating cover was down to the stops. By 6 A.M. Tuesday morning auxiliary flushing water had to be provided, raw sewage being used for this purpose. Pumping of the digesters was continued 24 hours a day until Saturday morning by which time the major portion of the sludge had been pumped out.

The following Monday morning the mechanical crew took over, finished the flushing, and then did the de-scaling of the heating coils. Forty-four wheelbarrow loads of grit and scale were removed from the digester. The amount of flushing water used was 2.5 m.g., of which 1.9 m.g. was raw sewage and 0.6 m.g. city water. The digester was refilled with raw sewage the second Friday and was ready for operation again on the third Monday, or 2 weeks, from the day the work was started. The flushing required 120 man-hours, and the de-scaling and removal of scale and grit required 124 man-hours,

The 2.5 m.g. of flushing water was pumped to a 3 m.g. lagoon and the supernatant from there was brought back to the plant. After 2 days settling supernatant liquor from the lagoon contained 100 p.p.m. suspended solids and 105 p.p.m B.O.D.

The second digester was also cleaned in November, with comparable data. At the conclusion of the second cleaning and withdrawal of the supernatant liquor from the lagoon, the lagoon was approximately half full of sludge.

The scale removed from the coils varied from ⅛ to ¼ in. in thickness and had the following approximate analysis:

Item	Per Cent
Acid insoluble	6.1
R_2O_3	20.8
CaO	67.6
MgO	1.4
SO_4	1.3
Total	97.2

The digester cleaning was accomplished under the direction of Paul Brunner, chief chemist. As mentioned, Brunner utilized raw sewage for flushing and refilling the tank. The use of the raw sewage made it possible to fill the digester again until the cover floated, without any danger of sewage gas being present in any appreciable amount.

As would be expected, the heat transferred from the clean heating coils was appreciable. The first day circulating water temperatures were 120° F. to the digester and 72° F. from the digester. The temperature of the sewage with which the digester was filled was 64° F., and in 4 days' time the digester temperature was up to the low 80's. Within 2 weeks it had reached the low 90's.

Suffice it to say an external heat exchanger would be looked upon with favor at Fort Wayne.

GADGETS FOR SEWAGE WORKS

By Robert N. Galloway

Superintendent, Orange County Joint Outfall Sewer Treatment Works, Garden Grove, Calif.

The old saying that necessity is the mother of invention is as true around a sewage treatment plant as anywhere. When a treatment plant operator invents anything, however, it is known as a gadget.

At the Joint Outfall Sewer plant a few gadgets have been developed which may be of interest to other operators. In describing them the situations which led to their creation will also be briefly discussed.

Clarifier Inlet Baffle

A suspicion that the clarifiers were not as efficient as they should be was confirmed by taking settleable solids tests at the quarter points around the tank periphery and by adding dye to the clarifier influent at different rates of flow. It was determined that about 25 per cent of the clarifier was doing about 75 per cent of the work. This condition seemed to be due to the angle at which the sewage entered the influent diffuser well. After experiments with baffles of several types, a baffle with an "X" cross-section, which extended from about 6 in. below the top of the inlet feed pipe to the bottom of the diffuser well and traversed the diameter of the inlet diffuser well, was found to be the most satisfactory. With this baffle the inlet stream is divided into four parts and forced straight down, resulting in more uniform distribution throughout the tank.

Eliminating Scum Problems

An annoying problem developed with light material, which had escaped the bar screen, floating to the surface between the clarifier scum baffle and the effluent weir. This trouble was overcome by attaching an extension to the scum arm and fastening a rubber scraper on it which dislodges anything that catches on the weir.

In the citrus season considerable quantities of orange peel and pulp are received at the plant. Because of this material it wasn't unusual to find the clarifier scum troughs plugged and the sweeps gathering more scum and shoving it over the top of the trough. To remedy this trouble, a nozzle was attached to a water line and a valve installed which could be opened or closed by the clarifier scum sweep at the proper time. The trough is now flushed with each revolution of the scum sweep as the scum load is being dumped.

Automatic Sampling Device

In 1946 a weekly sampling schedule was started, with samples taken in proportion to the flow every half hour for 24 hours. This allowed the operator very little time for other duties, so the schedule was arranged for hourly samples, but still there wasn't much accomplished in the way of plant maintenance on sample day. The only answer to the problem was more gadets.

An old-fashioned paddle wheel was installed in the effluent flume, with the perimeter of a 24-in. wheel bearing against a small rubber pulley on the axle of the paddle wheel for speed reduction. A small cup was attached to the 24-in. wheel by means of an arm. At the bottom of each revolution this cup picks up a sample, spilling it into a trough at the top of the wheel revolution. The paddle wheel blades are tapered causing it to speed up with an increase in flow, thus taking care of proportioning the quantity of sample to the rate of flow.

The influent sampler had to be constructed to handle an 18-in. variation of the sewage level in the flume. In addition, there is considerable turbulence at this point, since the sampling station is at the diversion box into which the pumps discharge. Obviously a paddlewheel was out of the question, so a piece of pipe was bent in a half-circle, with a diameter of 18 in., and fitted at right angles to a horizontal pipe which extends through the wall of the diversion box. This half-circle pipe arrangement is rotated by a small motor through a series of gears. The open end of the half-circle pipe travels down through the fluid to the zero flow level and picks up a cross-section of sample in proportion to the amount of flow. The sample runs out through the horizontal section of the horizontal drive pipe when the curved section reaches the top of the revolution.

Chlorine Cylinder Rack Improved

Another gadget, which has made the connection of chlorine cylinders easier, is made with four ball-bearings, preferably about 4 in. in diameter. These are arranged in pairs on the chlorine cylinder rack at the place where the cylinder is connected to the feed line and form a sort of cradle on which the tank can be placed and turned so that the valve is in the proper position to be connected to the line.

Portable Digester Cover Scaffold

The floating cover of the secondary digester recently required replacement of all tie rods. In order to do the job, scaffolding had to be built. A conventional scaffold was erected around the center column of the cover to put up the center ends of the rods, but the ends which fastened to the skirt of the dome presented more of a problem because the bottom of the skirt is about 20 feet above the steeply-pitched digester floor. The added problem of moving a scaffold of this height from

FIGURE 1.—A-frame built for plant truck.

place to place around the digester would have made the construction and use of a conventional scaffold prohibitive. Also, to scaffold completely around the tank would require several thousand feet of lumber and a considerable amount of labor.

A gadget solved the problem. It had the appearance of a figure 4 with a very long leg, and when in place it hung upside down just below the bottom of the skirt, suspended by its leg to which a hook was bolted that hooked over the top of the concrete digester wall. The triangle formed by the figure 4 pointed toward the center of the tank and extended out about 5 ft. from the wall. When turned parallel to the wall it could be raised between the floating cover skirt and the wall to the top of the digester, enabling it to be moved from place to place.

Four of these inverted 4's were made and hung about 8 ft. apart inside the digester where they formed the framework for the scaffold. Flooring was laid across three of them, and, when the work was finished at one place, the floor boards were shoved on to the fourth scaffold holder, leaving one to be taken ahead ready for the next move. Two men worked on this platform throughout the job, and at times there were three men on it whose weight, together with equipment, would approximate 1000 pounds. The men were protected with safety belts at all times, and a fire extinguisher was kept on the scaffold in case of fire from the welding equipment.

Use of A-frame

Just prior to the task of repairing the digester, construction of an "A" frame, with an extension boom, for the truck was completed. When the boom is fully extended it reaches upward to 26 feet. It proved to be quite a time and labor saving device in hoisting steel, lumber, and equipment to the top of the digester. The "A" frame, Figure 1, is attachable to either end of the truck and is one of the most useful tools at the plant. Among other things, it has been used to pull the deep-well pump from the water well, to lift the bar screen out for repairs, to remove several tons of sand-blasting sand from a clarifier, and to carry heavy equipment around the plant. A small, high-pressure pump has been attached to the power take-off at the rear of the truck and is used for spraying weeds about the plant yard.

The above described gadgets which have been developed have more than proved their worth in the savings in time and labor they have made possible.

Editorial

TWO NEW PUBLICATIONS

Uniformity of practice, in so far as it is feasible under widely varying conditions, has many advantages. This aim is embodied in two new publications of the Federation, one dealing with sewage works accounting procedures and the other with technical nomenclature.

The Tentative Manual of Practice * entitled "Uniform System of Accounts for Sewer Utilities" is probably the first major effort to encourage the application of sound, basic accounting principles to sewage works administration. Before sewer revenue financing came into existence, only privately owned sewer utilities had to be concerned seriously about accounting procedures, and cost records on publicly owned facilities were usually smothered in the casual bookkeeping operations that encompassed all governmental functions of the municipality. This latter condition, unfortunately, is still much too common where state regulations do not prescribe municipal accounting procedures.

The accounting manual will probably be of greatest value where revenue financing is used, but its application in all cases is strongly recommended. A good system of accounts will furnish conveniently much information of value in the preparation of budgets, in the planning of improvements, and in routine management—all in addition to the basic data it provides for the establishment and adjustment of service charges in connection with revenue financing. The trend today is toward revenue financing, and cities adopting this method in the future will find the transition to be simplified and facilitated by a background of dependable accounting information. Also, uniformity of accounting practice will make it possible to achieve equitable comparisons of operation and annual costs between plants.

The manual does not attempt to set up an original accounting system, but instead adapts to sewage works functions the basic system that has been proved successful in the transportation, water works, gas, and power utility fields. Presentation of the "uniform system" is prefaced by a general introduction to the origin, principles, and mechanics of accounting. One appendix demonstrates practical application of the system to operation cost accounting; another illustrates application of accounting data in the development of a schedule of sewer service charges.

To F. M. Veatch, chairman of the Sewage Works Practice Sub-committee on Sewage Works Accounting, is due the major share of the credit for this useful bulletin. Mr. Veatch gave more than generously of his time and effort to the project, and his accomplishment in carrying the manual to the distribution stage in two years is indicative of the intense work that he has contributed. Serving with Mr. Veatch on the sub-committee are G. J. Beiswanger, C. A. Davis, A. A. Estrada, E. A. Farmer and S. I. Zack.

Feeling that the immediate demand for the accounting manual would not be heavy, the Board of Control has authorized distribution of mimeographed copies (by sale only) in tentative form. Printing of the manual

* Mimeographed, 117 pp., $5.00 per copy.

will be undertaken later if justified by the future demand. In the meantime it is hoped that experience with the tentative draft will yield constructive suggestions for revisions in the final issue.

Those who squirm when they hear references to "sewerage disposal plants" and similar misuses of nomenclature will welcome the appearance of the "Glossary—Water and Sewage Control Engineering," a joint production of ASCE, AWWA, APHA, and the Federation. This authoritative technical dictionary will bring about uniformity of terminology among all elements concerned with water and sewage control, including hydrology, irrigation, drainage, and power development, as well as water and sewage works. More than 4200 definitions and cross references are listed in the 276 pages of the book.*

The Glossary has been in preparation for about 13 years. Joint committees headed by Thorndike Saville and W. W. Horner carried on the early work, and Mr. Saville continued administrative leadership of the project into the production stage. An outstanding contribution was also made by Clinton L. Bogert, who spent more than a year in editing and collating the several lists of terms that had been gathered by the committees, with the aid of the National Resources Planning Board and others. The FSWA Committee on Sewage Works Nomenclature, comprising Clarence J. Velz, chairman, C. E. Keefer, and C. A. Emerson, has represented the Federation in the joint undertaking, and Mr. Velz has carried heavy responsibilities during the past two years in collaborating with others to complete the assignment. Altogether, an extraordinary amount of arduous and painstaking labor has been invested in the project, guaranteeing the excellence of the final result.

Every personal, company, and public engineering library should contain a copy of the Glossary. It is now the nomenclature authority for the writings and speech of all sanitary and hydraulic engineers—the basic standard for the preparation of reports, specifications, and technical papers. There has been a great and long-standing need for this book.

The ultimate value of both of the above publications will depend largely on the extent to which they are distributed and used. Uniformity of practice is certainly worth attaining in cost accounting and in nomenclature, and it is hoped that full advantage will be taken of the fundamental "tools" that are now available for the purpose. W. H. W.

* Members of the Federation and its constituent associations may place orders for the Glossary with the FSWA headquarters office. The special price to members is $1.00 per copy in paper cover and $2.00 in cloth.

Proceedings of Member Associations

NEW JERSEY SEWAGE WORKS ASSOCIATION

Thirty-third Annual Meeting

Trenton, New Jersey, March 10–12, 1948

The Thirty-third Annual Meeting of the New Jersey Sewage Works Association, held March 10–12, 1948, in Trenton, was attended by 362 members and guests.

This annual meeting was dedicated as a testimonial to Harry P. Croft in recognition of his thirty-fifth anniversary of service with the New Jersey Department of Health and his thirtieth anniversary as chief engineer. Mr. Croft was honored for his professional accomplishments as well as his outstanding work in behalf of the Association. In honor of the occasion, Mr. Croft was presented with a combination television-radio console as well as a hand lettered scroll containing the names of many friends.

The technical session on Wednesday, March 10, included a paper entitled, "The Effects of Stream Pollution on Industrial Expansion and Development in New Jersey" by T. Ledyard Blakeman, chief, Bureau of Planning, State of New Jersey. Discussion followed.

The program Thursday included the following papers:

"The Establishment of the Beverly Sewerage Authority" by G. Joseph Devine, chairman, Beverly Sewerage Authority, Beverly, N. J.

"Sewer Rentals" by Chester W. Paulus, mayor, New Brunswick, N. J.

"Controlling Infiltration" by I. Russell Riker, borough engineer, Princeton, N. J.

"Current Federation Affairs" by W. H. Wisely, Secretary-Editor, FSWA, Champaign, Ill.

Also featured on the Thursday program was the Plant Operators' Symposium, which included these discussions:

"Digitalis and Splints for Digesters" by I. O. Lacy, superintendent, Lockport, N. Y.

"Operating Experiences at the Tenafly Sewage Treatment Plant" by J. K. Adams, superintendent, Tenafly, N. J.

"Ninety Percent Removal Three-Stage Digestion" by A. J. Lanning, sanitary engineer, Fort Dix, N. J.

"Effects of Industrial Wastes on Sewage Plant Operation" by Sol Seid, supervisor, New Brunswick, N. J.

"Operating Problems at Maywood" by Henry VanDerVliet, superintendent, Maywood, N. J.

"The Economics of Sewage Treatment Plant Operation" by Leslie E. West, chief engineer, Elizabeth, N. J.; Paul Molitor, Jr., superintendent, Rutherford, N. J.; John Struss, superintendent, North Wildwood, N. J.; Elson T. Killam, consulting engineer, New York, N. Y.

The Friday session opened with the annual business meeting, at which time the following officers were elected for 1948–49:

President: Leslie E. West, Elizabeth, N. J.

First Vice President: John Struss, North Wildwood, N. J.
Second Vice President: Sol Seid, New Brunswick, N. J.
Secretary-Treasurer: Michael S. Kachorsky, Manville, N. J.
FSWA Director: Louis J. Fontenelli, Rahway, N. J.
Member Executive Committee: Harry P. Croft, Trenton, N. J.

A forum entitled "The Manufacturers Speak" succeeded the business meeting. Subjects discussed were chlorinators, Transite house sewers, high rate filter, sewer cleaning equipment, sewage pumps, grit conditioning, aerated grit chambers and pneumatic ejectors.

MICHAEL S. KACHORSKY,
Secretary-Treasurer

NEW YORK STATE SEWAGE WORKS ASSOCIATION

Twenty-first Annual Meeting

New York City, January 20–22, 1949

The New York State Sewage Works Association held its Twenty-first Annual Meeting at the Hotel Statler, New York City on January 20–22, 1949. A registration of approximately 500 members and guests established a new record for the Association.

At the technical sessions, the following papers were given, all of which were of outstanding interest:

"The Effect of Sea Water on the Bio-Chemical Oxidation of Sewage" by Professor Harold B. Gotaas, University of California, Berkeley, Calif.

"A Novel High Rate Anaerobic Waste Treatment System" by Harry W. Gehm, Technical Advisor, National Council for Stream Improvement, New York, and Phillip F. Morgan, associate professor, University of Iowa, Iowa City. Discussion by Eugene H. Trubnick, sanitary chemist, Anheuser-Busch, Inc., Old Bridge, N. J.

"A Report on Plans and Progress for the Tenth Edition of Standard Methods" by Harry A. Faber, chairman, Joint Editorial Board.

"Toward a Uniform Plumbing Code" (with motion picture) by Francis B. Elder, engineering associate, The American Public Health Association, New York.

"The Federal Works Agency and Water Pollution Control" by Major-General Philip B. Fleming, Administrator, Federal Works Agency, Washington, D. C.

"The 26th Ward Sewage Treatment Works, Brooklyn, N. Y." by S. W. Steffensen, project manager and deputy chief, Bureau of Sewage Disposal Design, Department of Public Works, New York City.

Feature of the noon luncheon program on January 21 was an address by the Honorable Harold C. Ostertag, chairman, Joint Legislative Committee on Interstate Cooperation of the State of New York. Mr. Ostertag gave an excellent talk on "Pollution Control Legislation in New York State." Also present at the noon luncheon was Secretary-Editor W. H. Wisely FSWA, who gave a brief address on "Federation Affairs."

Dr. George E. Symons, Chairman of the Memorial Awards Committee, presented the following awards in behalf of the Association: Kenneth Allen Memorial Award to Mr. R. S. Rankin in recognition of his paper on "Digester Capacity Requirements"; Lewis Van Carpenter Memorial Award to Mr. Wilbur N. Torpey in recognition

of his paper "Practical Results of Step Aeration."

At the business meeting, favorable action was taken to amend the NYSSWA by-laws whereby dues for Class A and Class B members after January 1, 1950 will be $8.00 and $6.00, respectively. This action was in accordance with the FSWA dues increase to $5.00 after January 1, 1950, when SEWAGE WORKS JOURNAL begins monthly publication.

Officers elected for the year 1949–50 were:

President: Paul E. Bardet, Flushing, L. I.

Vice President: John W. Johnson, Buffalo, New York.

Secretary: Ralph E. Sweeney, Rochester, New York.

Treasurer: J. C. Brigham, Albany, New York.

A. F. DAPPERT,
Retiring Secretary

SOUTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

Fourteenth Annual Meeting

Sioux Falls, South Dakota, September 29, 30 and October 1, 1948

The Fourteenth Annual South Dakota Water and Sewage Works Conference was held at Sioux Falls, September 29, 30 and October 1, 1948. This meeting broke all attendance records, both as to the total registrations and as to the number of municipal water and sewage works personnel attending. One hundred eleven members and guests were registered for the technical sessions.

The meeting opened with a Pre-Conference Smoker and Buffet Supper on the evening of September 29. The technical sessions were held in the auditorium of the Sioux Falls City Hall. At the first technical session Mr. George S. Russell, President, FSWA, presented a talk describing the new trends in sewage treatment. Mr. Ralph J. Johnson, sanitary engineer of the Missouri River Basin Office of the U. S. Public Health Service, Kansas City, Mo., discussed the Federal Water Pollution Control Act. Johnson stressed the fact that pollution control is still largely a responsibility of the individual states. Mr. W. F. Cochrane, sanitary engineer, U. S. Engineers District Office, Omaha, Neb., spoke on the design and construction of the water supply intake at Pickstown, S. D. This town is the site of the Ft. Randall Dam and due to the unusual geographical formations a rather unusual method was employed to develop a ground water source of supply.

The afternoon technical session was devoted to sectional meetings on water supply and sewage treatment. The Sewage Works Section was presided over by Leland Bradney, superintendent of the Sioux Falls sewage treatment plant. The session consisted principally of round table discussions covering the subjects of (1) small sewage treatment plant operation, (2) trickling filter care and operation, (3) the effects of ground garbage on sewage treatment plant loadings, and (4) general maintenance of sewage plants.

The annual banquet was held on the evening of September 30, with 147 members and guests attending. The banquet was the largest and most successful enjoyed to date by the association.

Technical sessions on the second day opened by a paper discussing operating changes in the trickling filter of the Sioux Falls sewage treatment plant,

presented by R. E. Bragstad, city engineer, and Leland Bradney, superintendent of sewage treatment, Sioux Falls, S. D. Mr. Walter Nelson, chief mechanic of John Morrell and Company, Sioux Falls, presented very worth-while information concerning the care and maintenance of electrical equipment. Methods of making and repairing paving cuts necessary for water and sewer lines were described by R. W. Dalthorp, assistant city engineer, Sioux Falls. The technical sessions were concluded by a talk on "Explosion and Safety Hazards at Sewage Treatment Plants," by C. R. Price, superintendent of sewage treatment, Rapid City, S. D.

The annual business meeting was held in connection with the Conference Luncheon on the last day of the meeting. Officers elected for the year 1948–49 were:

President: R. E. Bragstad, Sioux Falls.
Vice President: C. B. Madison, Winner.
Secretary: W. W. Towne, Pierre.

Following adjournment of the business meeting, association members enjoyed an inspection trip to the Sioux Falls water and sewage treatment plants.

W. W. Towne,
Secretary-Treasurer

TEXAS SEWAGE WORKS SECTION

1949 Annual Meeting

College Station, Texas, February 10, 1949

The 1949 Annual Meeting of the Texas Sewage Works Section was held during the Thirty-first Texas Water and Sewage Works Short School at Texas A. & M. College, College Station, Texas. The Short School, in session February 6–10, 1949, surpassed all previous meetings with a registration of 433 members and a number of guests.

The Short School program was especially well planned and diversified this year as in years past. Distinguished out-of-state speakers participating in the program were F. E. DeMartini of the Division of Water Pollution Control, U. S. Public Health Service, Washington, D. C.; Linn H. Enslow, President, American Water Works Association, New York, N. Y.; A. E. Griffin, Wallace & Tiernan Co., Newark, N. J.; W. A. Hardenbergh, Editor, Public Works Magazine, New York, N. Y.; W. H. Wisely, Secretary-Editor, FSWA, Champaign, Ill.

Highlight of the annual banquet session was the presentation of municipal awards by Dr. George W. Cox, State Health Officer of Texas. Those receiving awards: Mineral Wells for having the highest percentage of population connected to the sanitary sewerage system; Boerne, Crane, Llano and Jourdanton for having the greatest ratio of sewer connections completed during the year; Fredericksburg for making best use of its sewage plant effluent in irrigation; Corpus Christi for making industrial use of its sewage effluent; Austin for making best disposal of its sewage sludge by selling it as fertilizer; Dallas for maintaining the best sewage plant laboratory for control; Childress for maintaining the most attractive sewage treatment plant; Red River Arsenal for having the sewage treatment plant producing the best sewage effluent; Alice for completing the

greatest improvements to its sewage treatment plant during 1948.

Other awards were those presented by Mr. Earle W. Sudderth, Dallas, Chairman of the Committee on Awards, to the following: Honorary Life Memberships to G. L. Fugate, Houston, and Walter F. Hicks, Paris, in recognition of their exceptional service to the organization for many years; a $100 Government Bond to Mr. Clayton N. Billings, Austin, for his faithful and valuable service.

The annual business meeting of the Texas Sewage Section was held on February 10, Mr. J. P. Burden, San Angelo, presiding. A motion was passed by the membership inviting the FSWA to hold its annual meeting in Galveston at the first possible opportunity after 1951. The Arthur S. Bedell Award, conferred upon V. M. Ehlers in recognition of his many years of valuable service and assistance to the sewage plant operators in Texas, will be formally presented at the 1949 FSWA annual meeting. A committee was appointed to make the necessary provisions in the constitution for the increase in Federation membership dues, effective January 1, 1950, when SEWAGE WORKS JOURNAL becomes a monthly publication.

Officers elected to serve for the year 1949–50 were:

Chairman: Irving M. Dietz, Corpus Christi.

Vice Chairman: S. L. Allison, Corpus Christi.

Secretary: V. M. Ehlers, Austin.

MRS. EARL H. GOODWIN,
Assistant Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Florida Sewage Works Association	University of Florida, Gainesville, Fla.	June 5–11, 1949
New York State Sewage Works Association (Spring Meeting)	Governor Clinton Hotel, Kingston, New York	June 6–7, 1949
Alabama Water and Sewage Works Association	University of Alabama, Tuscaloosa, Ala.	June 9–11, 1949
Central States Sewage Works Association	Hotel Sherman, Chicago, Ill.	June 17–18, 1949
Institute of Sewage Purification (Summer Conference)	Harrogate, England	June 20–24, 1949
Ohio Sewage and Industrial Wastes Treatment Conference	Carter Hotel, Cleveland, Ohio	June 22–24, 1949
Louisiana Conference on Water Supply and Sewerage	Louisiana State University, Baton Rouge, La.	June 29, 30–July 1, 1949
Pennsylvania Sewage Works Association	Nittany Lion Inn, State College, Pa.	Aug. 24–26, 1949
Iowa Sewage Works Association	Hotel Kirkwood, Des Moines, Ia.	Sept. 20–22, 1949
Georgia Water and Sewage Association	Georgia Institute of Technology, Atlanta, Ga.	Sept. 21–23, 1949
West Virginia Industrial Wastes and Sewage Works Association	Ogleby Park, Wheeling, W. Va.	Sept. 21–23, 1949
Canadian Institute on Sewage and Sanitation	McIntyre Arena, Schumacher, Ontario, Canada.	Sept. 26–28, 1949
Federation of Sewage Works Associations	**Hotel Statler, Boston, Mass.**	**Oct. 17–20, 1949**
New England Sewage Works Association	Hotel Statler, Boston, Mass.	Oct. 17–20, 1949

Reviews and Abstracts*

The Use of Iron Pickle in Sewage Sludge Treatment. By Ronald Hicks. A paper presented at the Public Health and Municipal Engineering Congress (Br.), Nov. 19, 1948. 17 pages.

Although vacuum dewatering of sewage sludge is practiced widely in America, British progress in this field has been slow. Economic factors have hampered development of mechanical sludge drying in England, and, apart from the difficulties in air-drying sludge, the retreatment of drainage liquor has been causing growing concern because of increasing labor problems.

Raw sludge, conditioned with lime, has been dewatered hydraulically since 1880; several large plants still use this method and claim favorable economies. Mixed sludges, containing either activated sludge or humus tank residues, however, cannot be pressed satisfactorily even after lime treatment. Some success has been achieved through conditioning by heat treatment, and cakes containing 60 per cent solids have been obtained after pressing various sludge mixtures for 4 hours at 100 psi.

Recent investigations have shown that activated sludge can be dewatered from 1.3 to 25 per cent solids in 1 to 3 hours' press time after conditioning with 9 per cent ferric chloride, on a dry solids basis. In another case, elutriated digested sludge conditioned with 4 per cent ferric chloride, on a dry solids basis, was reduced from 5 to 40 per cent dry solids in 3 hours.

If a cheap and continuous supply of chemicals could be assured, more attention would be given to mechanical dewatering. The order of efficiency of conditioning agents has been found to be: ferric chloride, chlorinated copperas, ferric sulfate, aluminum sulfate, chrome alum. No large scale production of ferric chloride exists in England today. Present carload prices per long ton in England are: ferric chloride, anhyd., $160; copperas, $8 to $36; chlorine, $100; aluminum sulfate, $20 to $68; calcium chloride, 100%, $36; sodium silicate, 9.4% Na_2O, $34. Comparable quoted prices per short ton in the U. S. are: $115, $17, $50 (tanks), $30, $22, and no equivalent figure, respectively.

The steel industry in England uses about 90,000 tons of sulfuric acid and 10,000 tons of hydrochloric acid annually for pickling. The author presents a computation showing that it would be theoretically possible to treat all the sewage sludge from England and Scotland with iron salts from waste pickle liquor. He points out, however, that the liquor is difficult to handle and that the ferrous iron must be oxidized to the ferric state.

The author has studied the oxidation of hydrochloric acid pickle liquor with air and has concluded that the rate of oxidation is too low to be attractive commercially. He notes, however, that catalysts can be used to increase the oxidation rate, and this possibility is being investigated.

He studied the manufacture of chlorinated copperas, and found that the rate of absorption of chlorine varies considerably with temperature and salt concentration. Industrially, absorption towers packed with Raschig rings are used, and recirculation of the liquor is essential to get reasonable absorption efficiencies. He states that chlorine efficiencies of 95 per cent may be obtained with properly designed systems, but that 90 per cent would be a safer figure. On a basis of $100 per ton for chlorine and $16 per ton for ferrous sulfate (20 per cent ferrous iron), he calculates that chlorinated copperas could be made for about $45 per ton and states that this figure is too high, especially when it is realized that the compound is not nearly as effective as ferric chloride.

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

Electrolytic oxidation of ferrous iron appears to offer the cheapest means for producing ferric chloride from spent pickle liquor if the liquor contains sufficient free acid to permit the oxidation to go to completion. His calculations show that 1954 kw.-hr. would be required at 100 per cent efficiency to oxidize a ton of ferrous iron at a potential of 4 volts. Assuming 90 per cent efficiency (experiments have shown this to be reasonable), and power at 1.7 cents per kw.-hr., it would cost about $36 to oxidize 1 ton of iron as ferrous chloride to ferric chloride, whereas direct oxidation with chlorine would make the cost about $70.

He suggests that electrolytic tanks be operated in conjunction with pickling, or that electrolytic pickling be adopted where the stock to be pickled is fairly uniform. In the latter case the pickling tanks would be built in the form of half-cells. One half-cell would contain the acid and associated ferrous salt, and the steel being pickled would be the negative electrode. The other half-cell, separated from the first by a porous diaphragm, would contain the spent pickle, and carbon plates suspended therein would form the positive electrode. One of the most important factors in such an operation would be the diaphragm. This would have to be strong enough to withstand the pressure when one-half of the tank is emptied, yet porous enough to permit adequate diffusion. Sheet asbestos lightly impregnated with rubber was found to be the best diaphragm material from the viewpoint of low voltage loss, and some diaphragms have been in continuous use for 3 years without disintegration. A new ceramic membrane is being developed which should be available soon for commerical use.

This paper was written to outline various lines of attack on the problem, rather than to present the detailed results of 2000-odd experiments, in the hope of stimulating interest in large scale investigations.

RICHARD D. HOAK

Proceedings of Second Annual Meeting, West Virginia Sewage and Industrial Wastes Association, Clarksburg, West Virginia, September 30 to October 1, 1948. 54 pp. $1.00. (Available from Association, State Capitol, Room 643, Charleston, West Virginia.)

The following papers were presented to the membership which includes governmental, industrial, manufacturing and consulting personnel:

The Treatment of Coal Washery Wastes to Avoid Stream Pollution. BY HENRY F. HEBLEY.

With increasing mechanization of coal mining, coal washery wastes contain greater quantities of colloidal matter, clay, fine coal and silt. The author outlines industrial practices for reducing pollution to streams by these wastes from anthracite and from bituminous washeries. In anthracite industries, 3-hr. retention settling basins may be used alone or in conjunction with mechanical thickeners. Underflow may be slushed into abandoned mine workings or filtered. Flocculents may be necessary in the thickeners, lime—1.7 tons per ton of solids, and starch—0.2 lb. per ton of solids. Parton has shown that it is possible to segregate from the settled fines a marketable product by flotation separation of material larger than 200 mesh.

Bituminous wastes contain also iron sulfide (pyrite), an additional problem. Coal is cleaned by difference in specific gravity of coal and refuse. Washery water, for recycling, must be cleared of a certain proportion of fines to keep the proper water density. From Parmley, the most suitable means of maintaining a solids balance is to bleed off a continuous volume of water containing excessive solids. Part of this is clarified in thickeners, sometimes using lime and causticised starch.

The Ohio River Compact and Others Operating in the United States. BY KENNETH S. WATSON.

Four tables summarize the historical development of the Ohio River Compact; the data for computing contributions of the eight states to maintenance of the Commission; the existing Interstate Pollution Control Compacts with their duties and authority; and the existing Interstate Pollution Control Agreements which have less authority.

Compacts are ratified by the U. S. Congress, and their commissioners may be authorized to set water standards, minimum waste requirements, and issue orders against pollution offenders.

The Ohio River Compact specifies removal of at least 45 per cent of suspended solids from domestic sewage. Of all compacts, that for the Ohio River covers the greatest number of states (8), the greatest drainage area (154,880 sq. miles), and the largest population (15.8 million).

Financing of Sewers and Sewage Treatment. By Roy H. Ritter.

Financing of sewerage systems is best accomplished by general obligation bonds where possible. For Martinsburg, W. Va., this could not be done because of legal restrictions. However, an ordinance made it possible to combine existing water and sewer systems as well as future systems. Expansion of the sewerage system is being financed by a 30-year bond issue. Payment of principal, interest, and operating expenses of both water and sewer systems will be made from revenues from metered and flat use of water (70 per cent), sewer construction charges levied against houses connected—not vacant property (18 per cent), sewer service charges (7 per cent), and miscellaneous (5 per cent). The sewer service charge is 10 per cent of the water bill. The sewer construction charge is $6 per quarter per house, to cease when all bonds are retired.

Industrial Waste Definition and Records. By K. N. Bundy and P. E. Jordan.

To be published at a later date in This Journal.

Plans for Clarksburg Sewage Treatment Plant. By Herman F. Lundberg.

A treatment plant for an equivalent population of 66,000 has been designed for the Sanitary Board of Clarksburg. Plans also include improvement and extension of the sanitary sewers. Primary and secondary treatment were outlined and briefly explained. Total sludge digestion space is about 4½ cu. ft. per capita. The estimated cost is $2.9 million, which would require a charge of about $2.00 per month per unit served.

Symposium—The Oxygen Balance—Assets and Liabilities

1. Introduction. By Dr. D. V. Moses.

A general outline of the oxygen assets (D.O.) and liabilities (B.O.D.) of a stream.

2. Sampling and Preservation. By A. A. MacQueen, Jr.

Referring to the work of a number of investigators, the author points out the necessity for (1) accuracy in sampling to obtain representative data; (2) the selection of sampling points in relation to stream characteristics and waste outfalls; (3) the choice of adequate displacement samplers (2 bottles recommended); (4) collection of a sufficient number of samples to show variations in stream and in wastes.

Concerning preservation of samples, neither refrigeration nor acidification is satisfactory for all types of oxygen determinations, though acidification fixes the oxygen system in samples of some trade wastes and sewages.

3. Chemical Oxygen Demand and Oxygen Consumed. By Dr. K. M. Madison.

Standard B.O.D. methods do not give accurate or reproducible results when applied to all trade wastes because of presence in many cases of substances toxic or inhibitory to sewage microorganisms. This paper contains discussion of available chemical means of measuring pollution which diverge widely from B.O.D. measurements.

After outlining chemical methods using potassium permanganate, potassium dichromate, chromic acid, ceric sulfate and iodic acid, the author points out that dichromate methods seem to offer the best solution to the problem of strength of trade wastes.

Twelve tables show comparisons of various dichromate oxidation methods with each other and with B.O.D. methods. Any of the three dichromate methods (Ingolls and Murray, Moore *et al.*, and Madison) could be used in estimating the strength of wastes.

Bernard D. Tebbens

Recent Developments in the Treatment of Industrial Effluents. By B. A. Southgate. A paper presented at the Public

Health and Municipal Engineering Congress (Br.), Nov. 15, 1948. 16 pages.

This paper briefly discusses some of the more important advances, both American and British, made in methods of waste treatment during recent years.

In biological treatment the British have done little work on recirculating filters, but feel that because their streams are smaller and a greater degree of treatment is required, alternating double filtration is to be preferred. Recirculating filters are suggested for partial treatment of paper mill wastes, where discharge can be made to municipal treatment plants, and this use is being investigated by the British Paper and Board Industry Research Assn.

Treatment of milk wastes by double alternating filtration has almost become standard practice in England, although some dairies prefer chemical coagulation, sedimentation, and single filtration. Cider manufacturing wastes have been treated by biological filtration, but the deficiency in nitrogen makes the addition of an ammonium salt necessary.

The oxidizing ability of the percolating filter is being used to treat the manufacture of rayon by the viscose process, and to remove phenol and formaldehyde from waste waters resulting from the manufacture of synthetic resins.

Gas for domestic use is made in almost every town of any size in Britain and the waste liquor is usually treated in admixture with domestic sewage. A committee studying the gas plant problem has recommended that (1) ammonia in the wastes be recovered, (2) modifications be made in the process to reduce the content of the higher tar acids and thiocyanate, and (3) discharge to sewers be at a uniform rate.

Ammonia and higher tar acids were found to be relatively resistant to biological oxidation. The only satisfactory method found to keep the ammonia content low is to remove both free and fixed ammonia by use of lime and steam distillation. Tar acids can be reduced by treating the gas in an electric tar precipitator before putting it through the condensers and scrubbers.

Wastes resulting from the pickling of copper slow down or stop biological action in trickling filters and digesters, and kill fish in streams. Experiments by the Ministry of Agriculture and Fisheries have shown that copper sulphate may be toxic to trout in concentrations of 1.3 p.p.m. $CuSO_4$ (0.5 p.p.m. Cu).

The preferred treatment for copper pickling liquors in Britain is by electrolysis, either in the pickling vat or at a central plant. Up to 97 per cent of the copper has been recovered from the dilute rinse by treating the liquor with scrap iron. Usually the treated effluent must be neutralized with lime before discharge.

In the electroplating industry a treatment plant has been installed in England for wastes containing copper (up to 300 p.p.m.), zinc (up to 110 p.p.m.), tin (up to 300 p.p.m.), and iron (up to 200 p.p.m.). Treatment is by a batch process. Milk of lime is added and mixed by agitation with compressed air, the mixture is settled for 6 hours, and the supernatant is drained off in 6 hours. Sludge is drawn to drying beds. The effluent when diluted with an equal volume of water is non-toxic to fish.

Wastes containing chromates inhibit nitrification in treatment processes, cause excessive accumulation of film on rock, and reduce the efficiency of biological treatment when in concentrations as low as 1 p.p.m. Treatment with barium salts or ferrous sulphate and lime is advocated.

Experimental work has shown that cyanides can be oxidized on filters when in concentrations lower than 30 p.p.m., but any fluctuations in the load caused deterioration in the quality of the effluent. Pretreatment with lime and ferrous sulphate has been used but where complete treatment is needed the use of lime and chlorine is recommended.

The paper also mentions the re-use of industrial liquids. In the paper industry save-alls remove fibers from water to be re-used. In the sugar beet industry settling and screens are being used to condition, transport, and process water for re-use. At the end of the season the remaining water is successfully treated by applying it slowly to percolating filters. Aerobic retting of flax makes it possible to re-use the retting wastes.

W. A. HASFURTHER

Microbiological Problems in the Manufacture of Sugar From Beet. Part 1. Corrosion in the Diffusion Battery and in the Recirculation System. BY L. A.

ALLEN, A. CAIRNS, G. E. EDEN, A. B. WHEATLAND, F. WORMWELL, AND T. J. NURSE. *Journal of the Society of Chemical Industry* (England), **67**, pp. 70–77 (1948).

Extraction of sugar from sliced beets by hot water in batteries of diffusion cells results in a residual liquid made up of two increments, water separated from the spent cossettes after discharge from the cells and water pressed from the spent beet (or pulp) in the process of preparing this material as cattle food. This liquid contains appreciable quantities of soluble constituents of the beet including 1.5 per cent sucrose and considerable amounts of suspended matter. If wasted, this liquid of high polluting characteristics may present serious problems of stream pollution. Recirculation of the combined battery water and pulp press water to the battery water supply tank, thus reusing this waste liquor continuously in the process of diffusion, is being used by many factories to avoid pollution. Difficulties in connection with this procedure comprise (1) corrosion of recirculating equipment and of diffusion cells, brought on by acidity developed from bacterial growth in the circulating liquid at normal process temperatures of 45° C. to 55° C.; and (2) fermentation resulting in the formation of organic acids and of gas.

This paper describes an investigation of the factors responsible for corrosion in a battery employing recirculation and involving the isolation of microorganisms producing acidity, the measurement of corrosion occurring in different parts of the battery, and the effectiveness of chlorination and other remedial measures in checking acidity and in reducing corrosion.

Reference is made to the remedial measures that have been recommended in the literature by workers. These have involved adjustments of the temperature of recirculated process waters; adjustments of pH; chlorination of beet wash water to destroy soil bacteria; and, mechanical filtration, acidification and sedimentation with the reuse of clarified waters. Previous writers have advanced the theories that corrosion may not be due entirely to the degree of acidity, and have mentioned the action of sand on metal parts and the action of diffused oxygen on metal surfaces as important factors. Consideration has been given to the kind as well as to the quantity of acid.

In this study examinations and analyses of bacterial flora of recirculating liquid resulted in the isolation of lactobacilli of the *L. delbrucki* type, micro-aerophilic organisms, aciduric as well as acid forming in characteristics. Innoculations of sterilized samples of recirculated liquid with pure cultures of lactobacilli when incubated at 45° C. resulted in the rapid formation of acid in 3 to 4 days, lowering of pH from 6.9 to 3.5. Although developments were slower at 55° C., some strains resulted in a reduction of pH to about 4.5 in 3 to 4 days. Growth of the organisms was definitely retarded at 70° C.

Subsequently a study of the bactericidal action of different doses of chlorine on lactobacilli was made, comparing counts in innoculations of chlorinated and unchlorinated sterilized recirculating liquid. A dose of 40 p.p.m. of chlorine destroyed 99.7 to 99.96 per cent of the bacteria after a contact period of 25 to 30 minutes. A much smaller dose indicated effective prevention of the growth of the organisms.

Alternately with the bacteriological investigation, neutralization of acid in the recirculating liquid with lime for the reduction of corrosion was suggested. Using small plates of mild steel at different locations in the battery water recirculation system, tests were made under known conditions of pH, titratable acid, and temperature. These were compared with similar tests when the battery recirculated supply water was neutralized with lime. Treatment with lime reduced corrosion in the battery supply tank to 4 per cent of that occurring in untreated liquor. In lime treated liquid, corrosion in a few isolated areas produced penetrations even deeper than occurred in untreated liquid. This suggested a potential danger unless well controlled neutralization is practiced. Over-dosing with lime may afford protection to large areas but may cause intensified attack on isolated small areas. Although it appears that the addition of lime may be strikingly successful, the conclusion is that, if practiced, it should be carefully controlled to prevent the value of pH from rising above 7.0.

Continuous chlorination on a laboratory scale and on a factory scale was conducted. In the laboratory, an application

of 50 p.p.m., resulting in residuals in the recirculated liquid varying from 0.5 to 1.0 p.p.m., virtually inhibited the formation of acid. In the factory scale experiment using a commercial chlorinator, the application of chlorine varied from 18.7 to 48.6 p.p.m. with the following results:

1. pH values were maintained at a high level (above 5.5) with minor fluctuation during periods of chlorinations.

2. Comparatively few plate counts on yeast extract-dextrose agar of battery supply water and returned water with chlorination in operation suggest that lactobacilli were markedly decreased with doses of 31.6 to 48.6 p.p.m.

3. Corrosion on test plates inserted in the sand tank represented a uniform attack and was reduced 15 per cent of that occurring in the untreated liquid by a chlorine application of 18.7 p.p.m. Increasing chlorine dosage to as much as 48.6 p.p.m. had very little additional effect.

4. Corrosion of test plates inserted in the battery pit was less when exposed to untreated liquor than that of test plates in the sand tank. Likewise, reduction of corrosion by chlorination was less, amounting to one-third to two-thirds of that produced in the untreated liquor. Maximum reduction occurred with a chlorine application of 48.6 p.p.m.

5. Chlorination did not materially affect the corrosion taking place in the diffusion cell.

6. The high rate of corrosion in the sand tank suggests acceleration of the acid attack by the flow of liquid. Further, the abrasive action of sand and pulp probably tend to interfere with film formation which otherwise would serve as a protective coating.

7. Although chlorination had a marked effect in reducing the corrosion in the return water circuit and may be effective in an application less than 18.6 p.p.m., it should be understood that it can not do more than raise the value of pH to that of fresh beet juice which normally is in the range of 5.5 to 6.5. The latter is comparatively high but on the acid side, permitting corrosion to proceed at an appreciable rate.

8. Chloride contents of samples of second carbonization juice, as a result of chlorination of recirculated battery water and pulp press water, fluctuated considerably, but the average values indicated little significance.

9. Chlorination did not appear to make a consistent or significant difference in the levels of sugar content of pressed pulp and of pulp press water, or in the levels of purity of juice and of the elimination of non-sugar substances. No effect of battery loss could be assessed.

10. Chlorination did appear to increase the moisture content of pressed pulp, probably because the pulp is less easily compressed as pH values increase.

BRUCE M. MCDILL

Nationalization of the Sanitary Services of Rosario, Santa Fe, Argentina. *Revista de "Obras Sanitarias de La Nacion,"* **12**, 126 (June 1948).

The Argentine national government purchased the properties, works, installations, and various facilities pertaining to the water-supply and sewerage services of the municipality of Rosario. Action was taken because these facilities were still operated privately; extensions of sanitary services by private capital were not being made because investment returns were not adequate; and densely populated sectors of the municipality, principally populated by the less privileged, were without essential sanitary services.

Purchase of facilities was made from Consolidated Water Works Company of Rosario, Ltd., and Rosario Drainage Company, Ltd. for a price of 2,182,539 pounds sterling.

LE VERNE D. HUDSON

Industrial Wastes. BY G. ROUSSE. *L'Eau* (France), **35**, 165–168, 189–191 (Oct., Nov. 1948).

The conception of separate treatment of industrial wastes has not progressed far in France. Each case requires separate study, but acceptable solutions of the problems are possible. Collaboration of industry with competent administrative agencies is needed to alleviate conditions detrimental to public health. There are a considerable number of sanitary technicians available, but laws to enforce industrial waste treatment are insufficient. A description of modern treatment meth-

ods for specific conditions, administrative procedures, and possible methods of changes for treatment are given.

W. RUDOLFS

Pickle Liquor Neutralization. By Richard D. Hoak, Clifford J. Lewis, Charles J. Sindlinger, and Bernice Klein. *Industrial and Engineering Chemistry*, Vol. 40, pp. 2062–2067 (Nov. 1948).

This is the fourth in a series of papers dealing with waste pickle liquor treatment. Whereas previous papers dealt with reaction rates and sludge characteristics, this paper is concerned with economic factors and the applicability of various alkaline neutralizing agents.

Factors which affect the choice of alkaline agents are: (1) those fixed by the agent such as basicity, delivered price and reactivity, (2) those fixed by conditions at the mill such as operating schedules, treatment area available, character of receiving stream or sewer system.

Data on the cost and reactivity of various alkaline agents are presented. Information on sludge settleability is also given. Alkaline agents considered include sodium hydroxide, sodium carbonate, ammonia, magnesium oxide, calcium hydrate, quicklime and limestone.

Conventional neutralization of waste pickle liquor involves mixing the proper amount of alkaline agent with the liquor until the reaction is complete. Split treatment involves neutralization of free acid and precipitation of ferric iron with limestone followed by the application of a costly but more reactive agent to complete the treatment. A dolomitic limestone is unsuitable for this application.

Caustic soda (sodium hydroxide) is the most reactive of all the common alkaline agents but its price is high and generally this compound should be used as a supplement to a much cheaper material. Soda ash appears to have no place in the pickle liquor field because of its high cost and because of its low reactivity in comparison with caustic soda. Ammonia is costly and will not precipitate iron completely. Its use is uneconomical except under special conditions in large mills. High calcium lime has low cost and high reactivity to recommend it. However, the supply of high calcium lime is limited at present and is likely to continue so for several years. Low reactivity is the principal objection to dolomitic lime but this disadvantage can be overcome by aeration of the mixture. Pulverized high-calcium limestone is a cheap, plentiful agent but its reactivity is low. The reactivities of limestones from different sources vary widely. Dolomitic limestone is too unreactive for pickle liquor treatment. Precipitated chalk is more reactive than natural calcium carbonate and when available as a chemical industry by-product, sells for only a slightly higher price. Cement dust has a variable reactivity. It should be a plentiful low cost material, however. Acetylene sludge (impure, hydrated, high-calcium lime) is a by-product of acetylene generation and is sometimes available at a low price. Magnesia has a high basicity and offers possibilities for by-product recovery but its cost is high.

Pilot plant experiments suggest that on a large scale the difference in reactivity between dolomitic and high calcium limes may be less than indicated in laboratory experiments. The pilot plant tests have also shown that by varying the type of lime and the method of mixing, sludges of widely different dewaterability can be produced. Repeated runs have shown that for a given set of conditions the same type of sludge is always produced.

Data are given on two sludge dewatering runs.

Eight tables of data. Eight graphs. Three references.

PAUL D. HANEY

Dry Lime Treatment of Waste Pickle Liquor. By C. J. Lewis. *Iron Age*, **163**, 48–53 (Jan. 20, 1949).

The author reports on results obtained from operation of a pilot plant for investigation of waste pickle liquor neutralization. The work was done by the Warner Company, under Mr. Lewis' supervision, in cooperation with steel and equipment manufacturers.

Vacuum filtration of sludges produced in conventional neutralization of pickle liquor with lime slurry has generally been unsatisfactory because of the slimy nature of the slurry; centrifugation of such material has also been impractical for the

same reason. The author found that filterability could be greatly improved by treating the waste liquor with an excess of dry lime. This treatment method results in a relatively granular sludge that dewaters rapidly in a basket-type centrifuge or by vacuum filtration. Where the slurry is dewatered by centrifugation, the effluent must be passed through a polishing filter if suspended solids must be removed completely.

Using 300–400 per cent excess high calcium or dolomitic lime to treat representative pickle liquors, the data show substantially complete precipitation of iron, and a centrifuge rate of 21 to 74 lb. of dry solids per square foot per hour. Sludge cakes contained 38 to 45 per cent moisture.

Although this procedure uses a large excess of lime to improve filtration rate, it has the advantage of holding slurry volume to a minimum, thus reducing the total volume that must be handled. The author points out that his proposed process would be applicable chiefly where waste liquor volumes are relatively small, i.e., perhaps several thousand gallons per day. Where large volumes must be treated, the advantages gained from dry lime treatment would not justify the cost of the excess lime.

Four tables of data are included.

RICHARD D. HOAK

Recent and Prospective Developments in Sewage Purification at the Outfalls of the London County Council. By E. H. VICK, G. S. CLEMENTS, AND A. BRUCE. Inst. Sewage Purification (Great Britain) Preprint (Nov. 19, 1948).

The two outfalls of the London County Council serve an area of 180 sq. mi. and a population of about 4.5 million. Since 1890, precipitation works have been in service, using lime and ferrous sulfate in the early days. In 1895 sludge vessles were acquired to run the sludge into the North Sea about 55 mi. from the outfalls. The works effluent enters the tidal River Thames.

Experimental work has been carried on since 1892, first on contact beds (1892–1903) and later on activated sludge. In 1928 the Council began construction of a 5 to 10 million Imp. Gal. (6 to 12 million U. S. gal.) daily activated sludge plant at Barking. Between 1935 and 1940 the works were enlarged to handle 60 million Imp. (72 million U. S.) Gal. per day. This plant uses surface aeration (Hartley type) with reaeration by diffused air. Sludge digestion has also been explored (with heat since 1932), and since 1938, in a working plant for 200 tons of solids daily, heated directly by steam. Since 1942, experimentally, sludge has been composted with refuse for use on farms.

The Northern Outfall Works handles an average of 180 million Imp. (216 million U. S.) Gal. per day, varying from 60 to 300 million Imp. Gal. The sewage is treated by sedimentation in covered basins of brick. Nominally, each channel is shut down for 60 hours, the supernatant decanted, and the sludge swept out manually.

The four sludge vessels carry 1,500 tons each, carrying 25,000 tons per week to sea.

The Southern Outfall Works handles an average of 100 million Imp. (120 million U. S.) Gal. per day. 7,500 tons of sludge are carried to sea weekly.

The settling channels are covered, and equipped in recent years with electrically driven scrapers, running day and night.

Operations are controlled jointly by the Chief Engineer's and the Public Health Departments of the London County Council.

Some war damage occurred.

Considerable construction was under way in 1948 at the Northern Works, adding detritus pits, additional heated sludge digestion capacity (1,200 tons per day); and at the Southern Outfall, remodeling the pumping station.

Present day (1947–1948) experiments cover recirculation of effluent in the activated sludge plant; secondary digestion; composting; mechanical removal of sludge.

The analysis for 1947 for the Northern Outfall show in p.p.m.:

Location	5-day B.O.D.	Suspended Solids
Raw Sewage	294.6	338
Preliminary Sed. Effluent	226.4	190
Weir Chamber Effluent	182.0	146
Activated Sludge Effluent	36.4	34

The sludge shipped to sea averaged—Water 95.07 per cent. The dry solids averaged—Loss on ignition 67.74 per cent; Total nitrogen, 3.09 per cent.

To improve the effluents, new works are proposed for primary sedimentation (mechanically cleaned); diffuser air activated sludge treatment (at present for 30 million Imp. Gal. p. d.); sludge digestion at 85° F., with external heating tanks and mixing by circulating pumps. Although the cheapest method of sludge disposal is by dumping at sea, there is a continued review of methods for returning sludge to the land.

LANGDON PEARSE

The Use of Digested Sludge and Digester Gas for the Production of Dried Gas. By H. G. LEIGH. Institute of Sewage Purification (England). Mimeo. preprint (1948).

At Blackburn, liquid digested sludge is irrigated on 400 acres of land rented to eight farmers. The sludge is pumped through 1.5 miles of force main and distributed once or twice a year at a cost of 6.5 pence (13 cents) per ton. The land receives two tons per acre per year. During the war, cereals were grown. The grass is cut at monthly intervals, when 6 to 8 in. long, and dehydrated for cattle fodder. A yearly yield of 5.5 tons of dry grass has been realized, with Italian rye or cocks foot grass. To improve the procedure, the sludge is to be digested with heat control, the sludge gas being used for drying grass. Grass dryers commonly used are low temperature, operating around 200° to 300° C. To secure uniform drying, a conveyor type of dryer is preferred.

The details of the final project are still in an experimental stage. It is estimated that if the dried grass can be sold for £30 per ton ($120.00), the cost of operation (including sludge digestion) will be paid (including fixed charges) and will reduce the cost of sludge disposal from 9¾ pence to one penny (approximately from 16.2 to 1.7 cents) per ton.

LANGDON PEARSE

West Middlesex Main Sewerage—Operational Aspects. By M. W. SUMMERS. *J. Institution of Sanitary Engineers*, Vol. 48, part 3, pp. 119–155 (Oct. 1948).

This paper describes in detail operational problems in the West Middlesex project. The main sewerage is divided into a high and low level area. The County receives sewage flows up to six times the dry weather flow, which is defined as 40 Imp. (48 U. S.) Gal. per cap. per 24 hr. The population served is nearly 1,400,000. Manholes have a maximum depth of 90 ft., and on the 10 ft. sewers may be 400 to 500 yd. apart. They are of two types, either a 2 ft.–7½ in. square brick shaft or a shaft of 2 ft.–9 in. diam. cast-iron pipe. The latter are most popular. The ladder rungs (⅞-inch diam.) project about 7 in. Chambers are built on the sewer for convenience. Flow is controlled by dam boards for repair purposes. Fifty-two flume recording gauges are installed, and 30 level recorders. Monel or stainless steel wires proved superior to braided copper. Hard rubber floats are used. Manholes have perforated covers. Air inlet shafts are placed about 80 yd. apart.

Average velocities exceed 3 f.p.s.

For working purposes, portable dry batteries are used, with an 8-watt bulb.

Routine maintenance is carried on by centralized gangs, under one foreman, familiar with the entire system, equipped with motor transport (carrying 6 to 8 men). No man over 55 years old is required to work in a sewer. The vans carry safety kits as well as necessary tools.

Precautions are taken to provide ventilation, check for gases by safety lamp, and prevent smoking within 5 yd. of a manhole. Two men are always present at the top of the manhole.

In the discussion, R. F. Pearson noted the failure of aluminum in contact with sewage and the experimental use of fans by London County for ventilation. Others commented on sizes of manholes, types of death recorders. W. T. Lockett stated that hydrogen cyanide gas was negligible in the West Middlesex system. He considered that not more than 10 p.p.m. of HCN should be present in sewage. The author noted that grit did not deposit in the sewers but was carried forward to the Mogden Works (5 to 6 cu. yd. per day being removed).

LANGDON PEARSE

The Effect of Cyanides on Treatment of Sewage in Percolating Filters. By A. E. V. PETTETT AND H. M. THOMAS.

Chemical Age (London), **59**, 779 (Dec. 11, 1948).

This paper was presented before a section of the Royal Institute of Chemistry, Dartford, England.

Waste waters from certain electroplating and metal hardening processes contain sufficient cyanides to render these liquids unsuitable for discharge to a river, or even a sewer. Other investigators have shown that HCN concentrations greater than 1 p.p.m. interfere with treatment of sewage by the activated sludge process. In the present investigation the effect of cyanide on treatment of settled sewage in experimental percolating filters was studied.

At an HCN concentration of 2 p.p.m. interference with nitrification was observed, and at 4 p.p.m. the B.O.D. of the filter effluent was appreciably increased. At concentrations up to 10 p.p.m., 98–100 per cent of the cyanide was destroyed by the filter, while the sudden addition of a dose of 30 p.p.m. to sewage treated in a filter inhibited nitrification and led to an effluent of extremely poor quality.

On continued application of this amount of cyanide, however, the filter slowly recovered its biological activity and eventually produced an effluent of satisfactory quality, free from cyanide. Interference with the operation of a filter was much reduced by pre-treatment of the cyanide by chlorination in alkaline solution. Effluent from a filter receiving sewage containing cyanide was toxic to fish when the effluent contained more than 0.1 p.p.m. HCN; effluent from a filter receiving pre-treated cyanide was slightly toxic, but became non-toxic when neutralized.

RICHARD D. HOAK

Maryland Water Pollution Control Commission: First Annual Report and Policy Committee Report, 1947.

The Commission, which began to function June 1, 1947, reports that it has investigated 107 pollutional complaints; inspected 237 industrial plants; made five minor stream pollution surveys; and made six sanitary sewage inspections.

Four regulations have been issued, as follows: (1) prohibiting discharge of oil from boats; (2) prohibiting disposal of garbage or food containers in open waters; (3) requiring food processors or packers to remove coarse particles from waste waters by fine-screening (1/32 in. mesh), and to provide additional treatment where necessary; (4) establishing standards of effluent quality for industrial wastes, but exempting acid mine water.

The ten standards established for industrial waste effluents are described in detail. This material was taken verbatim from a paper, "Standards for Industrial Waste Treatment and Disposal," presented by W. B. Hart before the Pennsylvania Chemical Society, March 26, 1948. It was the thesis of the Hart paper that the effect of a waste on stream ecology is much more important than the composition of any specific waste, and he proposed that the stream serve as a primary standard for qualifying effluents. He suggested maximum limits, for a group of waste water characteristics, that were not to be exceeded under any circumstances. If experience proved that the maximum limits were too high to permit gradual recovery of a polluted stream, appropriate maxima could be reduced until economic recovery would be insured. A determination of the biota normal to a stream under best-public-interest conditions would be made and the secondary, or effluent standards adjusted to permit development of such a biota.

The report of the Policy Committee is an excellent outline for agencies concerned with pollution abatement. It emphasizes the importance of basing decisions on *all* relevant facts and of serving the best interests of the entire State. It recommends that criteria and standards of water quality be established for Commission guidance, but not by regulation for uniform application, and to invite the views of interested groups before adopting standards. Cooperation with industry in seeking sound solutions for waste disposal problems is stressed throughout the report, and it states that standards of quality should be not only technically attainable, but also financially feasible, to avoid imposing burdens out of proportion to the benefits sought.

RICHARD D. HOAK

Periodicity of Dosing Percolating Filters.

The Surveyor, **107**, 567 (Oct. 29, 1948).

This article is a report of the discussion of a paper of the same name at the annual summer conference of the Institute of Sewage Purification. The original paper appeared in *The Surveyor* on July 30, 1948. It described laboratory and plant sized tests which indicated that feeding trickling filters in flushes at intervals gave better results than a more truly continuous feeding. In the plant tests the increase of time between flushes was accomplished by reversing one arm of the distributor, thus slowing the speed of rotation.

The subjects discussed included physical and mechanical effect, optimum frequency of dosing, ponding, suspended solids, dispersal of surface growths, and determination of time of contact.

T. L. Herrick

London's Sewage Outfalls: Prospective Purification Developments. By E. H. Vick and G. S. Clements. *The Surveyor*, **107**, 677 (Dec. 17, 1948).

The two outfall works of the London County Council handle sewage and storm water from an area of about 180 sq. mi. The population served is about 4,500,000.

The Southern Outfall Works handles sewage from London south of the Thames along with sewage from some districts outside the County of London. Preliminary sedimentation is the only treatment provided. Sludge is barged to sea for disposal.

The Northern Outfall Works serves the area north of the Thames. Some districts outside the County of London are also served. The average dry weather flow is about 180 m.g.d. (Imp.). Preliminary sedimentation is provided for the entire flow and activated sludge treatment is provided for 60 m.g.d. Extensions will be provided in two steps over a 10 year period. During the first 5 year period new primary sedimentation tanks will be built for half the flow, activated sludge treatment for an additional 30 m.g.d. and sludge digestion facilities sufficient to handle half the sludge produced. The second step will provide sedimentation tanks for the remainder of the flow and sludge digestion facilities so that the entire volume of sludge may be treated.

For about 50 years all sludge from the outfall works has been dumped at sea. At present 3 sludge vessels are available. There is a strong feeling that sewage sludge should be returned to the land, and various means of effecting this objective are under review.

T. L. Herrick

The Design of Detritus Tanks. By E. Dixon Grubb. *The Surveyor*, **108**, 3 (Jan. 7, 1949).

In this article the design of rectangular grit chambers is discussed. Design of an egg shaped channel with a rectangular outlet notch, proportioned to give a constant velocity at all depths, is included.

T. L. Herrick

What is Sewage Sludge and How is it Dealt With? By A. L. Abbott. Institute of Sewage Purification (South African Branch), Conference on Utilization of Sewage Sludge, Pretoria, South Africa (Nov. 1948).

This paper is a general discussion of types and characteristics of sludge produced from sewage treatment processes. Common methods of disposal of sludge are discussed as follows; direct disposal by dumping at sea and disposal on land, dewatering, incineration, lagooning, digestion, heat treatment, and composting.

H. Heukelekian

Sewage Sludge and Disease: The Role of the Sludge Digestion Process. By J. A. McLachlan. Institute of Sewage Purification (South African Branch), Conference on Utilization of Sewage Sludge, Pretoria, South Africa (Nov. 1948).

A review is given of the information available regarding the survival of disease organisms and their transmission by sewage sludge. Raw sludge is potentially more dangerous than the original sewage from which it is derived because of the greater concentration. The disease organisms which may be present in sludges are typhoid, amoebic dysentery, poliomyelitis virus, and ova of parasitic worms. Respective extent of danger from these

various types of diseases by the use of sewage sludge is not well established. Some of the recent information regarding the effect of sludge digestion and sludge drying on the survival of pathogenic organisms is reviewed. From the evidence it is concluded that the longest period of viability in sludges of any pathogens studied is 180 days in raw undigested sludges. Sludge digestion can reduce this interval of 3 months. True sterility can be obtained by heat treatment of the sludge.

H. HEUKELEKIAN

Disease and Sewage Sludge. By H. WILSON. Institute of Sewage Purification (South African Branch), Conference on Utilization of Sewage Sludge, Pretoria, South Africa (Nov. 1948).

The danger of disease arising from the use of sewage sludge as fertilizer is discussed. It is stated that there is no record during the past 100 years of an outbreak of disease which can be attributed to the use of sewage sludge as fertilizer. The disease organisms which may be present in sewage sludge are anthrax, bacillary and amoebic dysentery, typhoid, tuberculosis, parasitic worms, poliomyelitis, leptospira and brucella. Since these organisms are found in sewage sludge, then a potential danger exists. But there is a rapid mortality of the pathogenic organisms. The numbers surviving after a definite period of time under a given set of conditions will be dependent upon the initial numbers. The numbers of pathogenic organisms surviving in sewage sludge after digestion and drying on sand beds will be small compared with the numbers in raw sludge unless the numbers in the latter are large due to epidemics. There is an additional safety factor when the sludge is applied to the soil before planting as exposure to weather and soil organisms will reduce the number of pathogens and the chances of infecting a crop with pathogenic organisms are very small. Use of unsterilized sludge as surface dressing for vegetables is discouraged. Heat sterilization, chemical methods of sterilization such as lime and aerobic biological methods such as composting are considered as means of rendering the sludge safe.

H. HEUKELEKIAN

Some Thoughts on the Agricultural Importance of Sewage Sludge. By P. R. KRIGE. Institute of Sewage Purification (South African Branch), Conference on Utilization of Sewage Sludge, Pretoria, South Africa (Nov. 1948).

The author takes the stand that it is an unforgivable crime to discharge sewage sludge to sea or to incinerate it because of the loss of fertilizer value and makes a plea to return it back to the soil. The digested and air dried sludge is not best suited for fertilizer purposes but should be composted. Digested sludge is not immediately available food but must be converted by soil organisms into plant food but when composted it is a rich plant food. Dried digested sludge, screenings, detritus and scum have been successfully composted. The product from composting is semi-sterile because of the high temperatures (60° F.) allowed in the heap whereas digested sludge is not safe. Compost heaps are best prepared in a rectangular pit in layers of 1 ft. in depth, interspersed with layers of soil and with a light sprinkling of lime. The materials going into the heap should have the proper moisture content.

H. HEUKELEKIAN

Poliomyelitis and Sewage. By JAMES LEAR AND VERONICA MEASROCH. Institute of Sewage Purification (South African Branch), Conference on Utilization of Sewage Sludges, Pretoria, South Africa (Nov. 1948).

Samples of settled sewage and sand filter effluents collected from the Cydna plant in South Africa about a month after the last known case of infantile paralysis had occurred, showed the presence of poliomyelitis virus in the settled sewage but not in the sand filter effluent. Later a more detailed analysis showed the presence of a virus in the raw sludge, settled sewage and humus tank effluent. The virus could not be detected in the digested sludge (after 30 days) and sand filter effluent. There had been no clinical cases of poliomyelitis for two months prior to this. When an outbreak took place later, the virus was detected regularly in the settled sewage. Sometime after the epidemic abated the virus was not detected. Since the presence of virus reflects the

degree of infection of the community during an epidemic the infection is widespread and during periods when there is no epidemic the presence of the virus is not demonstrated. The effluent from a septic tank where an infantile paralysis case had occurred contained the virus two months later.

It is concluded that the presence of virus in sewage and effluents from sewage treatment plants of trickling filter type, does not result in the spread of the disease by contamination of water supplies, and wherever effluents are used for irrigation of crops and by insects. Vegetables irrigated with trickling filter effluents did not show the presence of the virus.

H. HEUKELEKIAN

Calm Approach to Radioactive Wastes Problem Urged. *Chem. and Eng. News* **27**, 7, 413 (Feb. 14, 1949).

Radioactive waste disposal problems were discussed at a seminar conducted by the Atomic Energy Commission in Washington, D. C., January 24 and 25, 1949.

Permissible limits and tolerances of radioactivity were discussed. Human tolerances can be determined through experiments and observation of those who have worked with x-ray or radium over the past 50 yr. It was noted that at least 4 radioactive materials are normally found in the human body. (Carbon, potassium, radium, and uranium.) Control of contamination can best be accomplished by close confinement and removal of the contaminants from the smallest possible volumes of air or water near the source. Isotopic dilution offers considerable promise; for example, radioactive carbon dioxide might be diluted with ordinary carbon dioxide.

Liquid wastes present a difficult problem. Most of the fission product waste has no present use and is stored in underground tanks and allowed to decay. At Oak Ridge, Tenn., it then passes to a large holding pond and then to a lake. The entire waste system is in a restricted area and the wastes are carefully checked.

One disposal method, which will probably be successful but laborious and expensive, is evaporation. A decontamination factor of at least 100,000 is possible by this method. The use of ion exchange resins is also under consideration, as is treatment of certain waste streams for recovery of non-radioactive material.

An activated sludge process for the treatment of radioactive wastes was discussed. Experiments at Los Alamos, N. Mex., have indicated that more than 95 per cent of a long-life alpha-emitter, such as uranium or plutonium, in concentrations up to 1.4 micrograms per liter, may be removed from the liquid and transferred to the sludge. It was predicted that biological concentration methods would be cheaper than chemical methods for removing radioactive materials from liquids.

The Atomic Energy Commission hopes to combat the tendency toward undue alarm regarding radioactive waste disposal by telling the public the problems involved and how they are being solved.

PAUL D. HANEY

Water Analysis. BY S. K. LOVE. *Analytical Chemistry* **21**, 2, 278 (Feb., 1949).

This paper presents a review of analytical methods developed during the last 5 years as applied to water analysis and reported in the literature.

The most important advance in analytical methods for water in recent years has been the adoption of instrumentation. Examples are electrophotometers, electronic pH meters, and flame photometers. Another outstanding advance has been the introduction of a large number of organic reagents specific for the quantitative determination of inorganic constituents.

Recently reported studies on the determination of silica, aluminum, iron, calcium, magnesium, sodium, potassium, copper, alkalinity, sulfate, chloride, fluoride, nitrate, nitrite, phosphate, dissolved solids, residual chlorine, dissolved oxygen, carbon dioxide, and organic matter are reviewed. Of particular interest to sewage works chemists and operators are the discussions on dissolved oxygen, chlorine, and organic substances.

The bibliography contains 155 references.

PAUL D. HANEY

Book Review

Water Supply Engineering. By Harold E. Babbitt and James T. Doland. McGraw-Hill Book Company, New York 18, N. Y. Fourth Edition. Price $6.50.

The Fourth Edition of this well-known text and reference has been enhanced by an improved format and higher quality paper. The enlarged page gives better appearance and readability. The index has been extended to include more than 4,000 items.

Many changes have been made in the text. The coverage of financing has been made more practical by the elimination of formulas and tables in favor of expanded discussion of financing methods. An explanation of the logistic grid has been added in the application of the Verhulst theory to prediction of future populations.

The chapter on ground water mechanics has been completely rewritten to include discussion of the "free surface curve" and a demonstration of approximation by the familiar Dupuit formula. The use and application of Ranney wells are emphasized.

The chapter on electrical equipment has been improved by replacing theoretical discussion with information on the characteristics of such equipment that are pertinent to selection. A method for the determination of the size, diameter, and number of stages in deep well pumps is presented, together with data on the jet well pump and an improvement in the methods of air-lift design.

Material on intakes, dams, and reservoirs has been rearranged, and a practical method for the solution of problems of water hammer and surge in long pipe lines is given.

Recent standard specifications are quoted in the chapter on materials with detailed reference to the ASA method of computing strength and thickness of cast iron pipe. Six principles of metallic corrosion are explained clearly.

The effect of elevated storage on distribution systems is shown analytically and graphically. The Hardy Cross system of network analysis is simplified, and the Conklin method for estimation of rates of flow in pipe grids is explained.

In the chapters on water treatment, methods and equipment for the dry feeding of chemicals are discussed more fully. The use of coarser filter sand, higher filtration rates, and improved methods of preparing water for filtration is recognized, with particular reference to Chicago experience. Modern chlorination practice, including break-point treatment, is given substantial coverage, and the principles of chlorination are simplified.

An appendix includes 217 typical water works problems, of which 27 were developed for this edition.

W. H. Wisely

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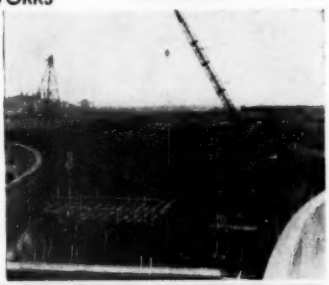

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Above: Eight 110' 6" Diameter Digesters with P. F. T. Floating Covers, *Northeast* Treatment Works, Philadelphia, Pa. (Bureau of Engineering, Department of Public Works, City of Philadelphia, Engineers).

Below: Closeup of one of eight P. F. T. Floating covers for 110' 6" diameter digesters at *Northeast Plant.*

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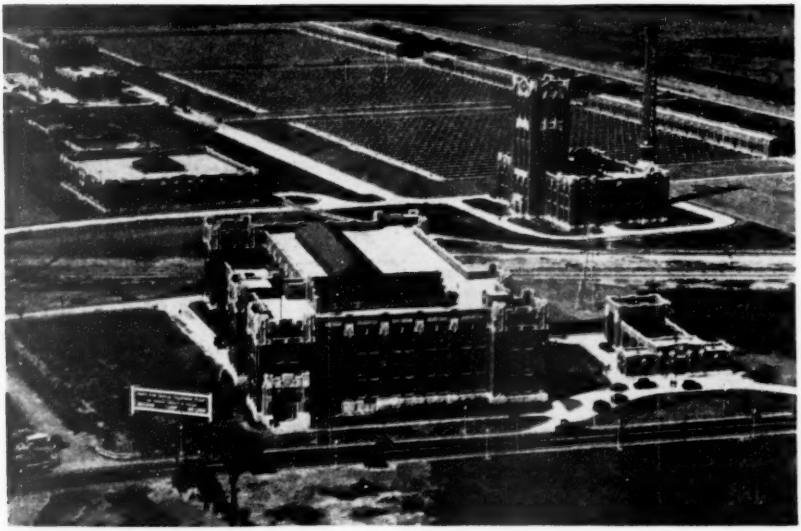

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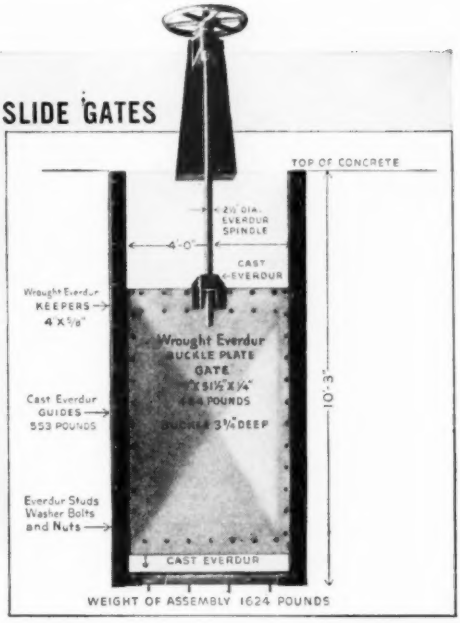
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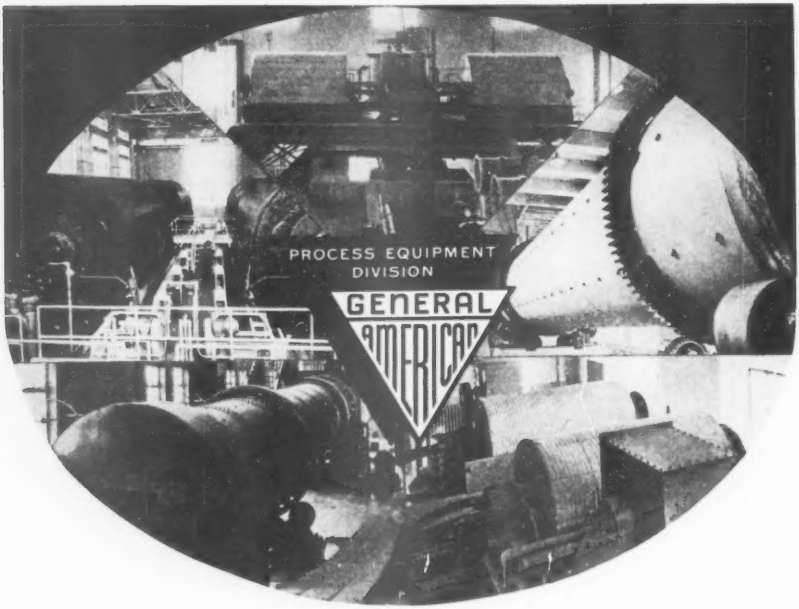

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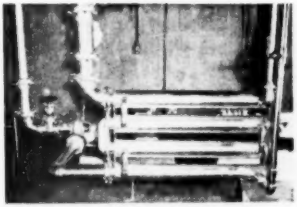

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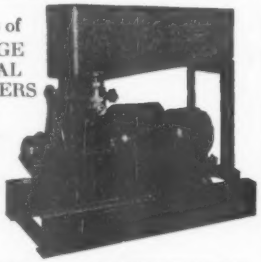

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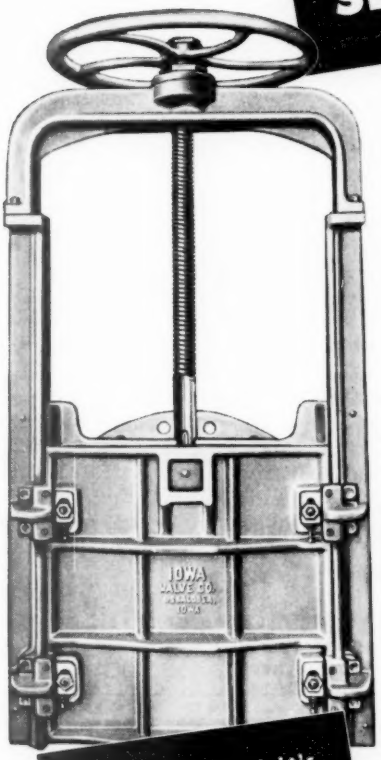

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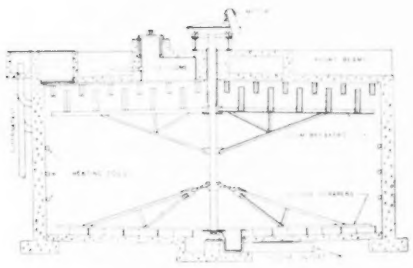

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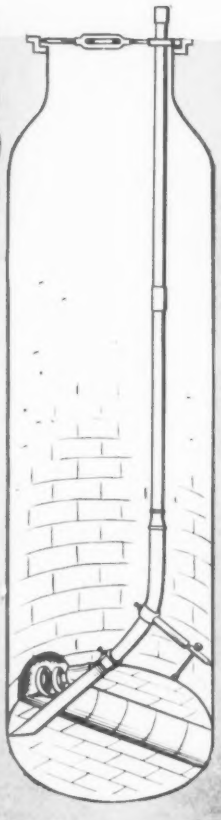

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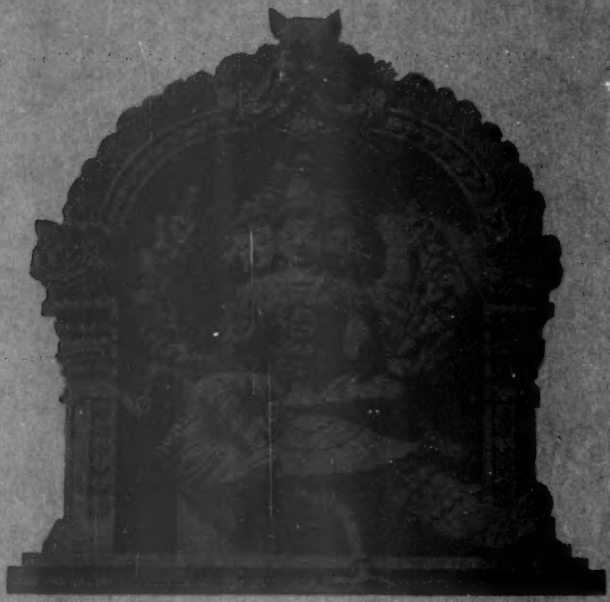

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